

METAL WORK

FOR THE STUDENT OF THE ARTS

HARRY A. JONES

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METAL-WORK

FOR GRADES VII, VIII, AND IX

BY

HARRY A. JONES

Machine Shop Instructor,
Technical School, Vancouver

*Authorized for use in the schools of
British Columbia*

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FOREWORD

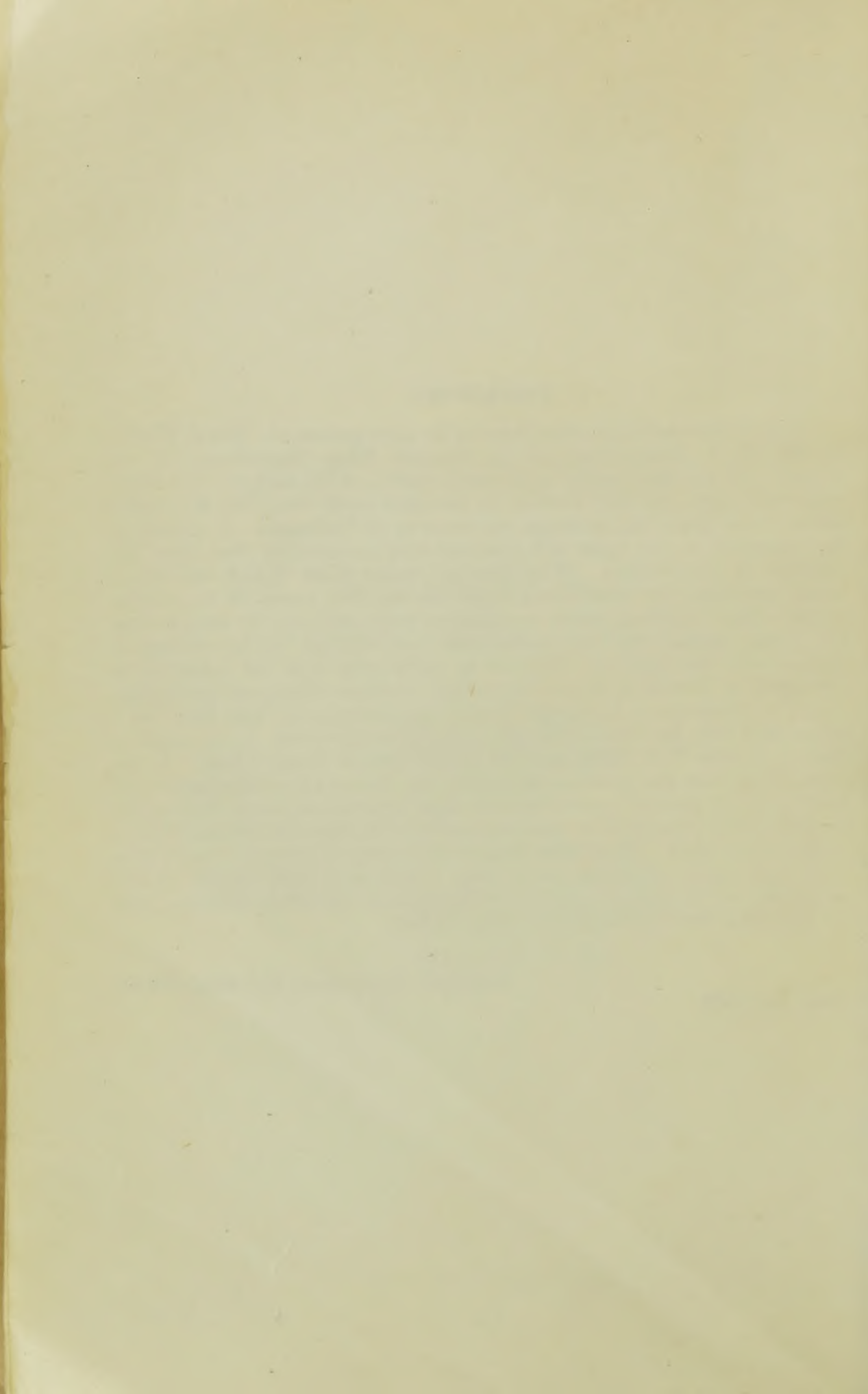
I have followed with great interest the preparation of "Metal-Work" by Mr. H. A. Jones, head of the Machine Shop Department of our School. He has been happy in the presentation of his subject. Too many such text-books are still wedded to the class-room idea, but Mr. Jones takes a new line, thus reviving the theories of Pestalozzi. A glance at the diagrams in the book will discover that instruction goes from the concrete to the abstract. With boys of Junior High School age this is sound practice. In nearly every case the boy first comes to know some actual object, working model, or machine part, and step by step is then led along, making his own deductions and relating his knowledge of Science and Mathematics. Thus at an early stage boys are subjected to the spirit of Technical Education, which vitalizes class-room knowledge.

The Vancouver Technical School has introduced this book as a prescribed text for Grade IX, the work in which grade is the same as that in Grades VII, VIII, and IX in the Junior High School. It has been found that the work is successful, the classes are enthusiastic, and the amount of ground covered greater than in previous years. The author has had wide experience in training teachers for High School and Junior High School work. This latest book is the result of years of observation and experiment. Striking, as it does, a new note and because of the simplicity of legends and clarity of diagrams, it will take a definite place in the curriculum of the Junior High School.

JAS. G. SINCLAIR,

Principal, Vancouver Technical School.

June 1st, 1932.



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PREFACE

This book on "Metal-Work for Grades VII, VIII, and IX" has been produced to meet a specific need in the teaching of the Industrial Arts in the Junior High Schools. While there are satisfactory text-books for the more mature students attending technical schools, there have been no manuals or texts suitable for younger pupils or in harmony with the principles underlying the Junior High School. "Metal-Work for Grades VII, VIII, and IX", by Harry Jones, is the first of a series intended to deal adequately with the Industrial Arts in the Junior High School.

A book which has such an end in view must satisfy certain criteria. It must, in the first place, lend itself to "exploration". To do this it must give the pupil contact with a wide range of typical experiences. If proper motivation is to be secured, the principle of pupil-purpose must be recognized. This means that the project method must be employed with projects that the pupil accepts as embodying purposes felt by him to be his own. This book provides for such projects, and the essential steps in a project (purposing, planning, executing, judging) have guided the author throughout.

But pupil-purpose, while giving drive, or the dynamic element, to the pupils' activities, must be reconciled with the objectives of the school, or, in other words, with the demands of organized society. Certain knowledge, certain habits and skill, and certain attitudes (to use the terms so often met in current educational literature), must be outcomes of the course. The author has kept this in mind and has effected a harmony between the aim of the individual, as expressed by pupil-purpose, and the social demands which are made upon him, as expressed by the school and its requirements.

"Metal-Work for Grades VII, VIII, and IX" provides for "exploration". Being based upon pupil-purpose, it secures the conditions most favourable for learning, or capitalizes them in the interests of the purposes of the school. From the projects problems naturally arise, and these are genuine problems, or felt-difficulties, and so they are the *fons et origo* of thinking. At the same time the whole process has a social reference. From this point of view the book may be thought of as the development through Metal-Work of the educational philosophy of John Dewey, with respect to both his psychology and his sociology. The author, however, is too skilful a teacher and too competent a craftsman to let the matter rest with that. He recognizes that in Industrial Arts as in Arithmetic there are certain fundamental "bonds" which must be formed and formed so well that they will last. As a result of the pupil's school experience there should be some permanent outcomes which will satisfy the pragmatist. The book is so arranged that these outcomes may be confidently expected.

H. B. KING,
Principal, Kitsilano High and Junior High School,
Vancouver, B.C.

June 1st, 1932.

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LEAD: PROPERTIES AND USES

Lead is one of the easiest metals for the beginner to work in and it requires very few tools. Its low melting point makes it possible for the pupil to use it in casting almost any form that he desires.

The chief characteristics of lead are that it is heavy, it resists water and acids, it can be cut easily, and it bends readily without breaking. It is self-protective against rust, because a deposit which forms on the surface acts like paint and prevents further action by atmospheric agents. Many old churches and castles have roofs covered with lead and they are thus still in good condition after centuries of exposure to the elements.

Forms of Lead. Lead can be purchased in pipe, rod, sheet, or ingot form. The sheet lead is usually measured by the Imperial wire gauge and is known by number. *Example:* No. 4 sheet lead means that there are 4 lbs. per square foot. This number 4 lead is 17 gauge (Imperial) and is approximately 1/16" thick. The bolts used in a battery are made of iron and then lead-coated to prevent them from being eaten away by the acid in the battery.

Toys are often made of lead, because of the ease with which they can be cast. *Lead paper* is used as a lining for tea chests, etc., to keep out moisture. *Type metal* is a lead alloy and generally consists of lead, 70 parts, antimony, 18 parts, copper, 2 parts, and tin, 10 parts. The antimony makes the alloy hard and causes it to wear well, while the tin imparts strength to it. This alloy, unlike that of other metals, expands upon cooling, so that the type comes from the mould with a sharp impression. Lead is added to many alloys to improve their machining qualities. *Example:* Common yellow brass, used in plumbing for ordinary valves, contains copper, zinc, and lead, in the proportion of 16, 8, and 1/2, by weight.

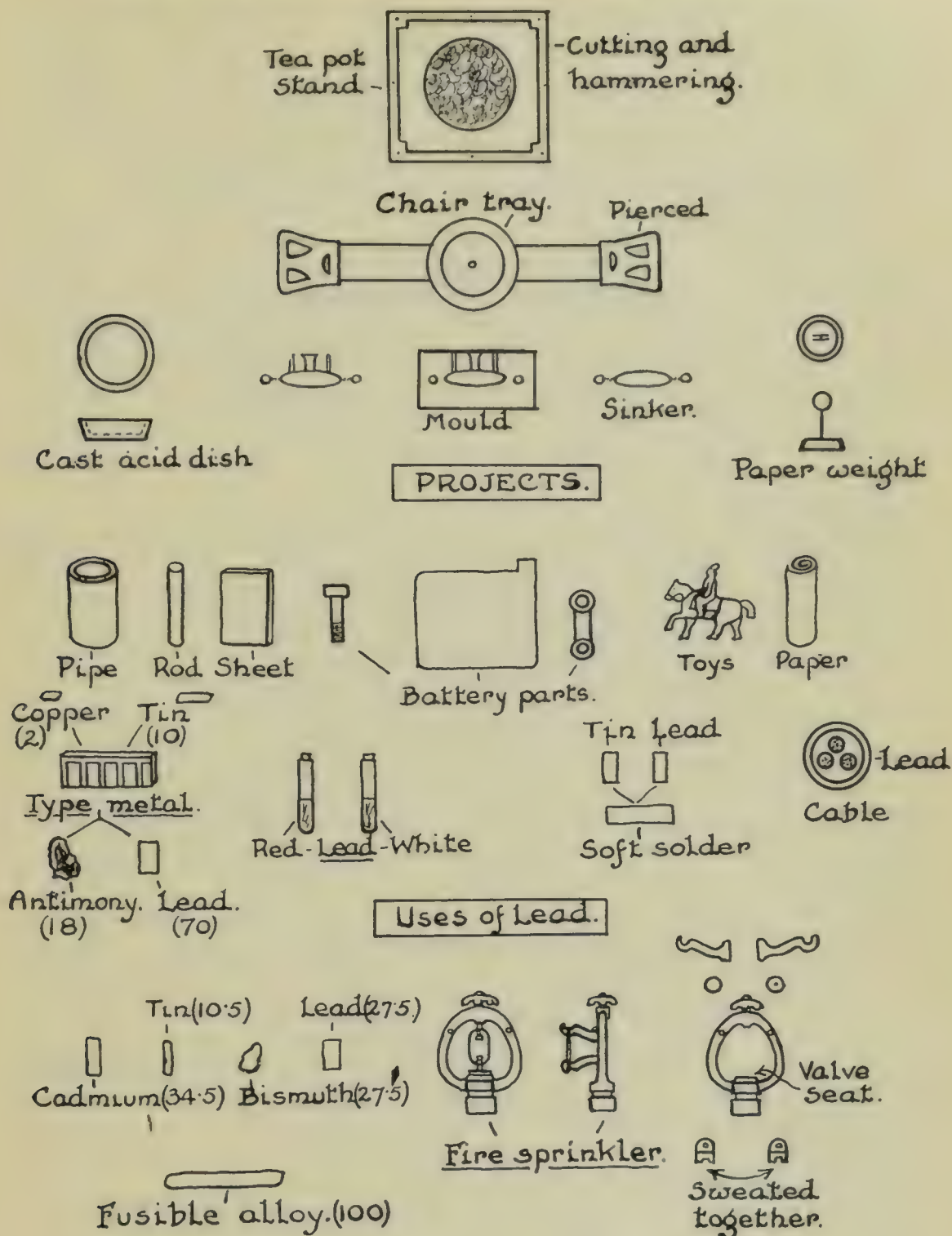
White lead. The oldest process for making white lead is still in use, and is known as the "Dutch process". It consists of placing lead disks in earthen pots, containing a little dilute acetic acid. The pots are piled in tiers and imbedded in tan bark, in such a way that air flows over them. White lead is mixed with linseed oil, forming a smooth easily worked and valuable paint.

Red lead is mixed with linseed oil and forms a valuable paint for the protection of iron work from rust.

Soft solder is composed of half lead and half tin and is the common solder for soldering. Underground and underwater cables are covered with an outer tube of lead, because lead lasts almost indefinitely and does not corrode.

Lead alloy. Fire sprinklers illustrate a very important use for a lead alloy. The two plates which hold the water-valve down are sweated together with a fusible metal, consisting of lead 27.5 parts, tin, 10.5 parts, cadmium, 34.5 parts, and bismuth, 27.5 parts. The peculiar thing about this alloy is its low melting point of 167° F. When heated beyond that temperature, the fusible metal comes apart and allows the valve to open for the water to rush out and extinguish the fire.

LEAD: ITS PROPERTIES AND USES (Continued)



Bearings. Lead is sometimes mixed with tin and antimony to make the cheaper grades of bearing metal.

Lead burning consists of joining two pieces of lead together by melting the adjacent edges and using tallow as a flux.

Babbitt is an alloy metal, usually consisting of varying proportions of lead, copper, tin, and antimony. It is used to line bearings in order to give them anti-friction qualities.

ORNAMENTING SHEET LEAD

Lead lends itself to the experiments of the beginner, because it is easily worked with very simple equipment. Projects can be made of lead where it is desirable to have a metal that possesses weight and malleability and that requires a decorative treatment of their surfaces. The metal does not rust and therefore lasts indefinitely. Its grey colour has the appearance of oxidised silver and makes a valuable enrichment for wood projects.

Working in sheet lead. The pupil will probably find it necessary to hammer the lead flat, owing to the wrinkles formed in the sheet while being handled. A block of wood or a wooden mallet should be used for this purpose. A metal hammer will mark the lead and make it thin, on account of the weight and concentration of the blow.

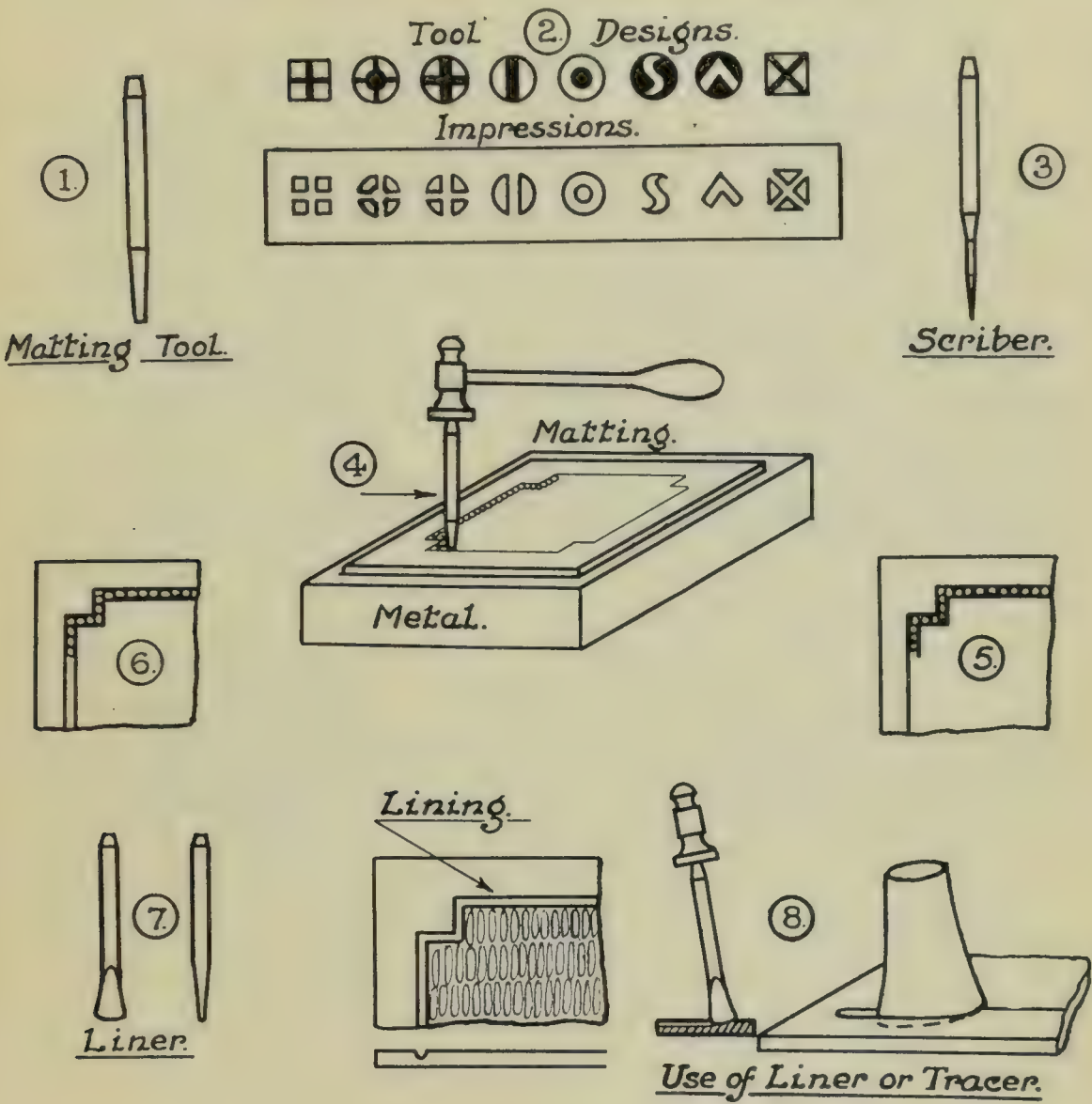
Cutting out. Sheet lead can be easily cut with a pair of shears after a line has been scribed on the surface with a steel scriber. If necessary, a pocket knife and a steel rule may be used to cut a straight edge.

Matting lead. Ornamentation may be applied by means of a matting tool, which should be made of tool steel; but, if this is not available, matting tools may be made from wrought-iron nails. Such tools will hold their pattern for a long time because the lead is quite soft.

Some patterns for matting tools are suggested in diagram (2). The patterns are cut on the tools with small files, needle files being usually used for this purpose. If tool steel is used for making the matting tool, it must be annealed first to make the steel soft so that it can be filed easily. After the pattern has been cut and tested on a piece of lead, the tool must be hardened and tempered. After the pattern has been transferred to the lead from the paper design by means of carbon paper, it is then outlined with a scriber (diagram 3). The sheet lead is laid flat on a smooth block of metal, as in diagram (4), so that the eye sights directly along the line away from the user. Place the matting tool vertical and give it light blows with a hammer. A repoussé hammer (diagram 4) is best suited for this purpose because it is light and has a broad face, which makes it easy to hit the punch when matting. Watch the line you are working to. If you are working to a single scribed line (diagram 5), work with the matting tool on one side only. Sometimes beginners find it easier to scribe two lines a distance apart equal to the width of the matting tool-point, as in diagram (6).

The lining tool (sometimes called a tracer), (diagrams 7 and 8). The lining tool is more difficult to use than a matting tool. As its name suggests, it is used to make a deep line in the metal, as in diagram (8). The tool is inclined slightly away from the operator and struck with light blows, which cause it to make an impression on the metal and to move slightly forward under each blow. A continuously even groove should be the ideal of the operator; and if the fingers are used to drag on the metal surface this can be accomplished. Liners can be made straight or curved and of different thickness according to the result desired.

ORNAMENTING SHEET LEAD (Continued)



ORNAMENTING SHEET LEAD (*Continued*)

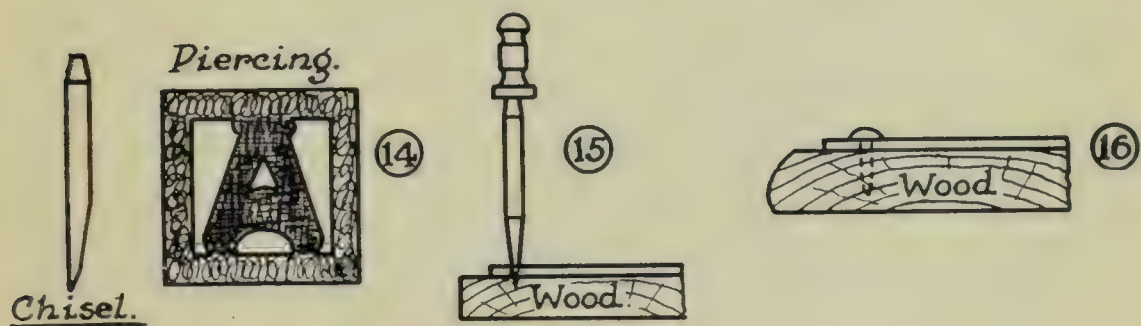
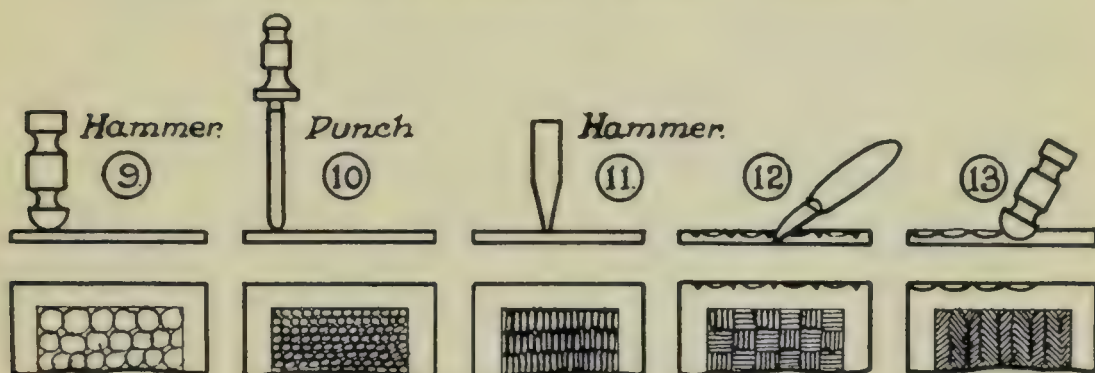
Hammered effects (diagrams 9, 10, and 11). A uniform smooth surface of metal is not very interesting. If hammered effects are used, contrasts can be made in the metal surface which provide interest. A ball-pein hammer produces spherical indentions, which are suitable for large spaces (diagram 9). A convex punch (diagram 10) produces smaller indentions for smaller masses. A straight-peined hammer (diagram 11) produces an agreeable contrast and is particularly suitable for square outlines. Do not forget that hammering the metal in this way hardens the metal slightly and stretches it. Therefore it is advisable to trim the edges of the metal to the exact size after the hammering has been done.

Decorating edges. Edges may be scalloped by cutting away with a knife, as shown in diagram (12), or curved indentions may be made with a ball-pein hammer, as shown in diagram (13). Such a treatment adds interest to the edge and makes the metal look thicker than it really is. The same effect may be obtained by bevelling the edges straight with a hammer or a scraper.

Piercing lead (diagram 14). Sheet lead can be pierced or cut out to shape by the use of wood chisels and gouges, as the metal is so soft that it will not damage them, providing it is cut on a wood block. The cut-out portion can also be trimmed to an exact shape with a pocket knife.

Punching holes. Holes can be punched after locations have been marked so that the lead can be mounted on wood. These small holes are put into the lead with a prick-punch, as shown in diagram (15). The lead is then fastened to wood with brass escutcheon pins (diagram 16).

ORNAMENTING SHEET LEAD (Continued)



CASTING LEAD

Lead is a very suitable metal to use for illustrating casting in a mould because of its low melting point (621 F.). Consequently, it can be heated readily over an ordinary gas stove. The idea of forming an article without cutting it to shape offers an interesting operation to the beginner. It introduces one in an elementary manner to the larger field of application in industry, where castings are made of cast iron, cast steel, brass, aluminum, etc. Industry first calls upon a pattern-maker, whose business it is to create wood patterns; after which the moulder in the foundry makes a sand mould, into which the metal is poured.

Casting a square block. This is perhaps the simplest kind of mould to use (diagrams 1 and 2). It is made of metal so that it can be used over again. It consists of two plates riveted together. The top plate has a square hole cut into it and filed with a slight angle, so that the casting can be removed from the mould easily. This taper, or angle, is called the "draw" (diagram 2).

Casting in a wood mould. Special forms can be cast by first making a wood mould in two parts, as shown in diagram (5). Diagram (6) illustrates one-half of a fish-line sinker mould. The two projecting pins "line up" the two halves of the mould and support the twisted wire which form the "eyes" of the sinker. The two halves of the mould are clamped together and, being made of wood, must not be pre-heated or it would burn. After this mould has been used two or three times, it becomes useless, because of the burning caused by the molten lead. Sand is used in foundries to form the mould because it does not burn. The wood pattern (diagram 7) is removed, leaving a space, as in diagram (8), into which the molten metal flows, filling the space and producing a casting, as shown in diagram (9).

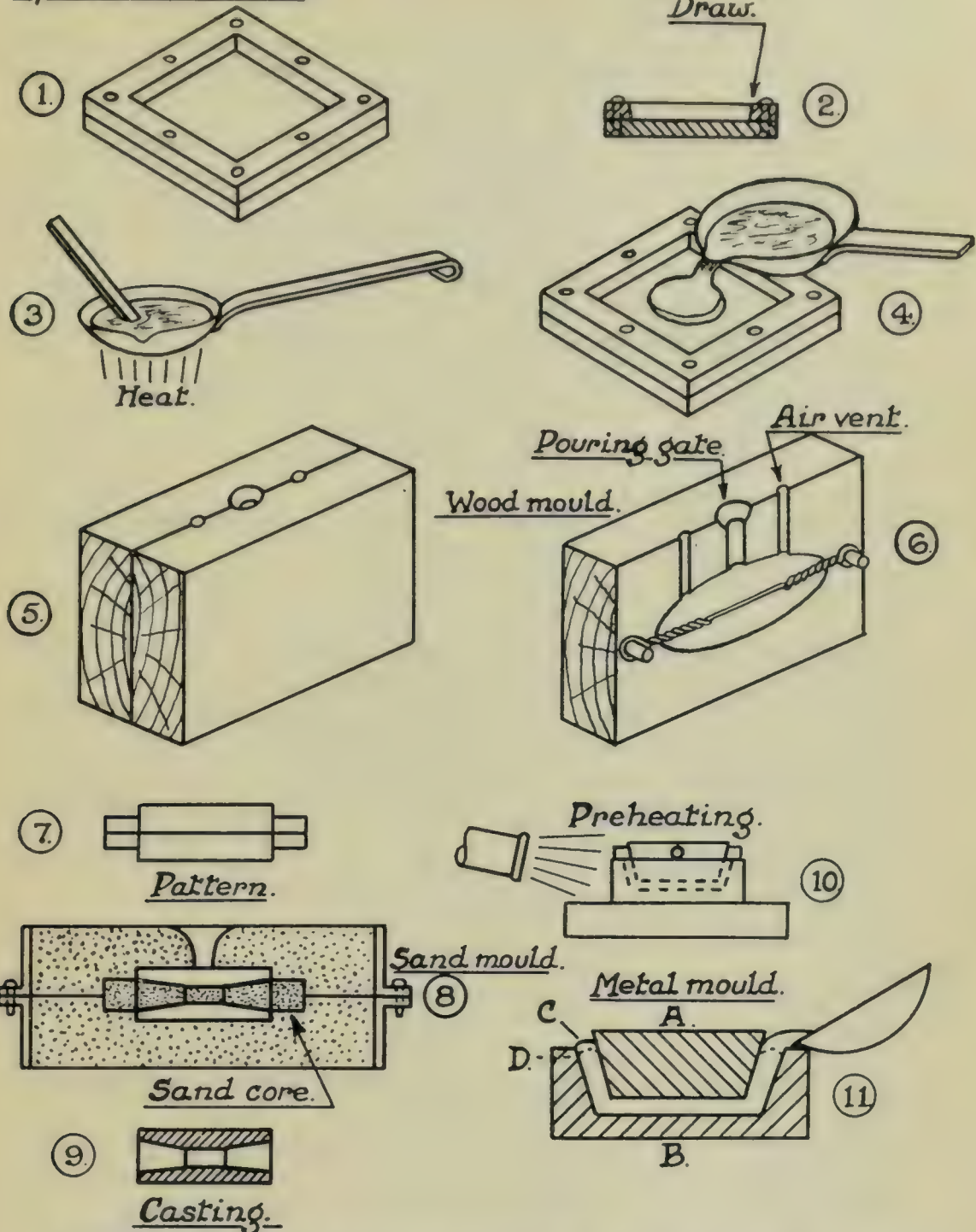
Casting lead dish for holding acid. A metal mould is used for this purpose, and unless the top part is heavy or is clamped down to the bottom part B, the lead will lift part A, being heavier than the cast iron. A piece of iron will float on a molten bath of lead because lead weighs .41 lb. per cubic inch and cast iron weighs .26 lb. per cubic inch.

Pre-heating the mould. It is very necessary that the mould be pre-heated before the lead is poured into it, because if molten lead were poured into a mould where moisture or water was present, steam would form beneath the molten metal and an explosion would take place.

Melting the lead. While the mould is pre-heating, sufficient scrap lead is put into a ladle (diagram 3) and the lead is melted over a gas flame or fire. Prepare an ordinary pine stick (diagram 3) about $1\frac{1}{2}$ inch wide and $\frac{1}{4}$ inch thick, and use this stick to test the correct pouring temperature of the lead. The stick should show black when immersed in the lead at the count of ten seconds. You will notice that a "scum" appears on the surface of the metal. This scum consists of impurities in the metal and also of lead oxide which forms on the surface of the heated metal.

CASTING LEAD (*Continued*)

Open metal mould.



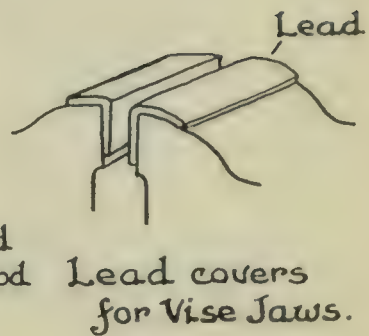
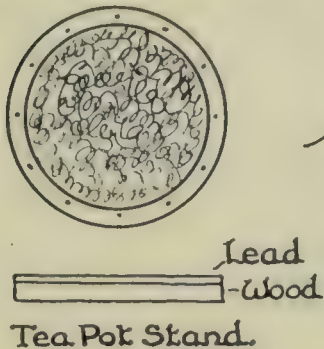
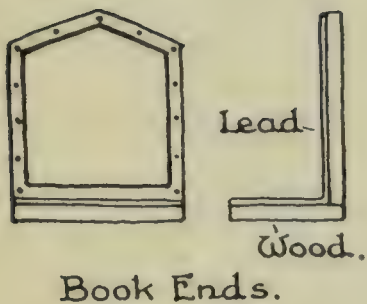
Pouring the lead. Before pouring the metal into the pre-heated mould (diagram 4) scrape off the scum with the flat piece of wood. Place the mould level and pour continuously until the mould is full of molten lead. If the operation stops and then pouring starts again, the metal will not be "homogeneous", that is, there will be a distinct line of separation in the metal structure and the casting will break.

Contraction of metal. The mould should be filled with molten lead, as at C, diagram (11). When the metal cools, contraction takes place and the metal drops to D, as shown by the dotted line.

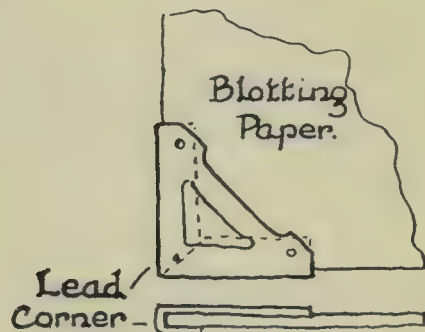
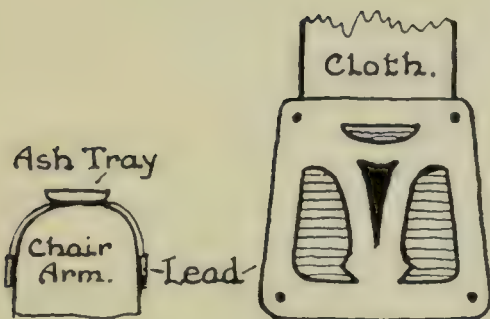
OBJECTIVE TEST: LEAD

1. Lead is a (hard) or (soft) metal?
2. Can lead be hardened?
3. Why is lead used as an outer coating for underwater and underground cable? Because it resists.....and does not.....
4. Lead melts at a (high) or (low) temperature?
5. Why is lead used as a lining for acid tanks? Because it.....acids.
6. Why is lead shot used in shot gun shells? Because they are and when they hit the object fired at.
7. When lead is cast it.....when cooling.
8. When soldering lead.....is used as a flux.
9. When casting lead, an explosion may be caused by the presence of.....
10. Lead is used to save life and property by its use in a.....alloy adopted in.....systems.
11. The four metals that make up this alloy are: (1) lead, (2), (3)....., (4).....
12. This alloy melts at a (higher) or (lower) temperature than the average temperature of the metals.
13. Lead is used on fishing lines because it does not.....and is.....
14. Lead is used in the manufacture of paint, because it.....wood and metal against the effects of.....
15. Lead is used for stair treads because it prevents people from and can be replaced when.....
16. Lead poured into a cold mould would be....., therefore the mould should be.....before being used.
17. Lead is sometimes used to cover vise jaws because it.....smooth or soft metals from being.....
18. Lead hammers are used because they are.....and do not.....
19. Lead is used to make batteries terminals, because it.....acids.
20. Why is lead sometimes added to copper and zinc to form brass?
21. What metal can be alloyed with lead to make it expand when cooling?
22. When is it better to have a metal expand when cooling? What practical application is made of this?
23. How is sheet lead measured? What do you understand by No. 4 sheet lead?
24. Sketch in section an open metal mould to cast round disks one inch in diameter and $\frac{1}{4}$ inch thick.
25. Sketch in section a sand mould, showing the casting box, pattern, and sand.
26. Sketch in section a casting which would require a core to produce it.
27. What does Babbitt-metal consist of? What is Babbitt-metal used for?

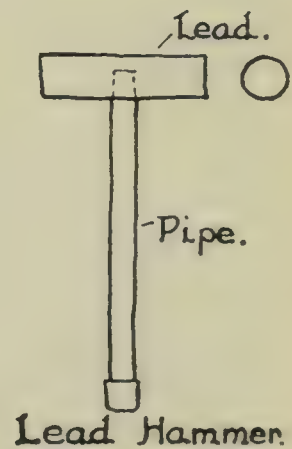
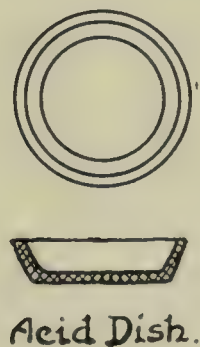
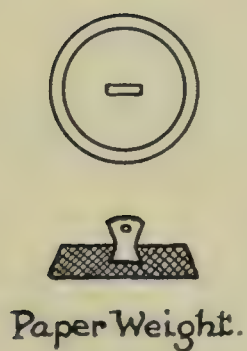
LEAD PROJECTS



CUTTING



PIERCING



CASTING

DIAMETER AND CIRCUMFERENCE

If a circular roller like that shown in diagram (1) is rolled on a flat surface without slipping, and if the flat surface is marked off, as shown, in divisions equal to the diameter of the cylinder, it will be observed that a point on the circumference of the roller passes a distance equal to three diameters and more. Now, if the diameter of the cylinder is divided into seven equal parts, it will be noticed that the amount the cylinder rolls past the third diameter mark equals one-seventh of the diameter of the roller.

Therefore, the circumference of the roller is equal to three and one-seventh times the diameter, or:

$$\text{Circumference} = 3\frac{1}{7} \times \text{diameter}.$$

This relation may often be seen symbolized by the Greek letter ‘ π ’, which is spelt ‘Pi’ and pronounced ‘Pie’.

Testing cylinders. It is advisable for pupils to test cylinders of different diameters. The circumference of the cylinders may be measured with strips of paper, as shown in diagram (2). A pencil is used to mark the circumference on the paper strip, after which the paper is stretched out flat and measured, as shown. The diameter can be measured with a rule or a pair of outside calipers. When the measurements have been taken on several cylinders of different size and the findings have been tabulated, it will be observed that in each case the circumference equal $3\frac{1}{7}$ times the diameter.

Precision measurements. For accurate application, such as the cutting of a gear, it is necessary to measure to $\frac{1}{1000}$ of an inch. For such examples the following relationship must be taken:

$$\text{Circumference} = 3.1416 \times \text{diameter}.$$

Eye bending experiment (diagram 3). If a strip $\frac{1}{2}$ " wide is cut from a tire inner tubing and small pieces of wire or wire nails are inserted at regular intervals, it will be noticed that, when the rubber strip is flat, the nails are parallel with one another. Bend the rubber strip to form an eye, as shown in diagram (3). It will be observed that on the outside of the rubber the nails are farther apart and on the inside they are closer together than they were when the rubber was flat.

Conclusion: In bending an eye the material must stretch on the outside and compress on the inside while the axis remains neutral.

In calculating length of material to form an eye, the calculation must be made on the mean diameter.

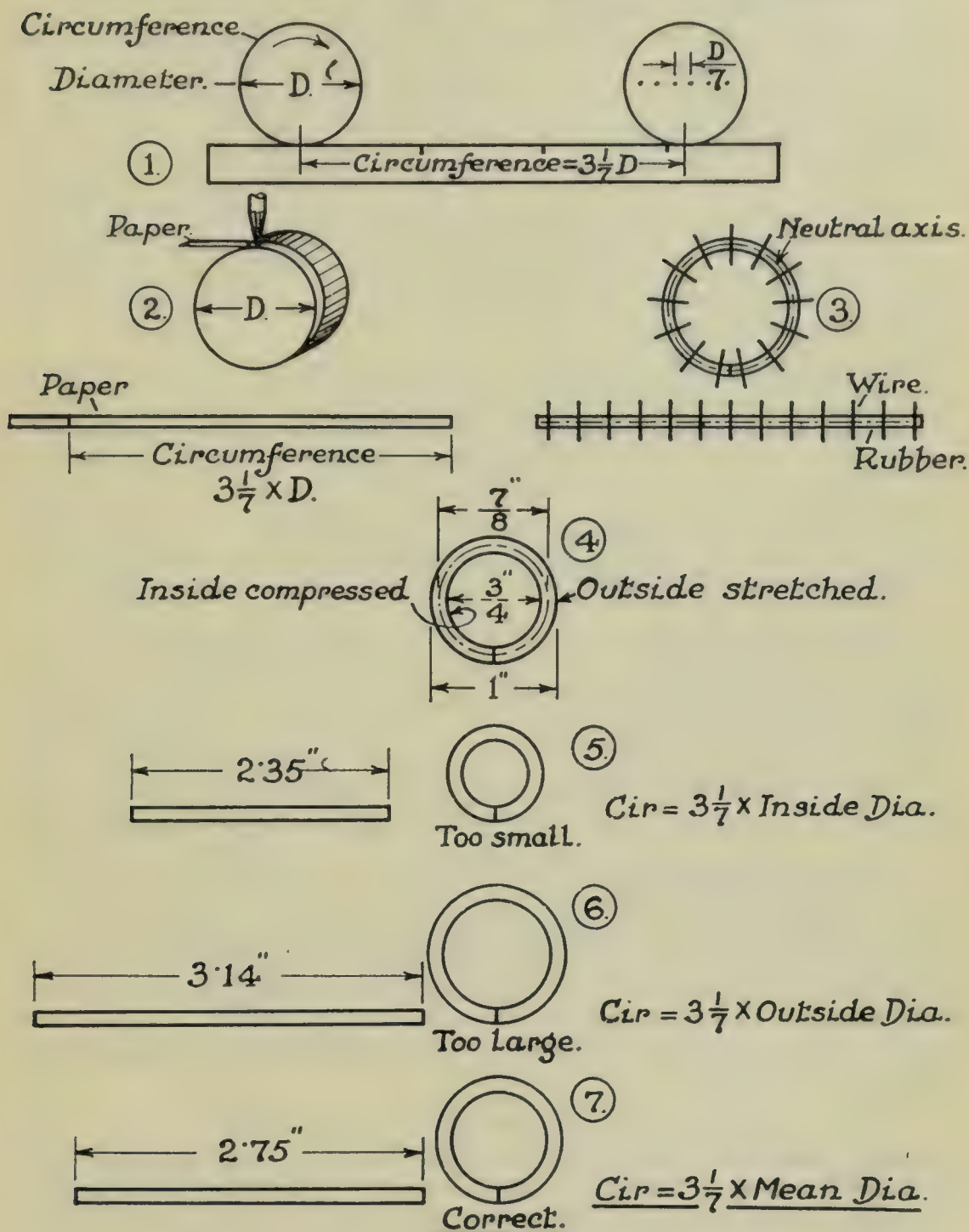
Application of calculation to eye bending. An iron ring shown in diagram (4), is required to be made to the dimensions given.

Diagram (5) shows the calculation made on the inside diameter, which proves to be wrong, because the ring obtained is too small.

Diagram (6) shows the calculation made on the outside diameter, which proves to be wrong, because the ring obtained is too large.

Diagram (7) shows the calculation made on the *mean or centre line diameter*, which *proves to be correct*, because the ring obtained is of the size required.

DIAMETER AND CIRCUMFERENCE (Continued)



IRON WIRE

Iron wire is made by rolling, as in diagram (1), and is then finished by drawing it through wire-drawing dies, which reduce the size of the wire gradually in steps, from one drawing to another. After each "draw" it is necessary for the wire to be annealed or softened. This operation consists of heating the wire to a bright red heat for a long period and allowing it to cool slowly. Diagram (2) shows a piece of wire being drawn through a die. The iron is soft as it enters the die, but the tension and pressure put on the wire harden it so that it must be annealed to make it soft for the next "draw".

Sizes of wire. Wire is made to gauge sizes, as illustrated in diagrams (3) and (4). The Stubs iron wire gauge is the one used. It is sometimes called the English Standard wire gauge or Birmingham gauge. Another gauge is used for steel wire. This is known as the Stubs Steel wire gauge.

Testing iron wire for size. Diagram (3) shows a piece of wire being tested for size, the numbers on the gauge designating the size. (A) shows the piece of wire is too big for No. 8 size. (C) shows it is too small for No. 6. (B) shows it fits correctly in No. 7; so the wire is No. 7 size.

If you desire to know the exact measurement of No. 7 size, turn to the reverse side of the gauge plate, and you will see that the decimal equivalent of No. 7 is .180.

Coating the wire (diagrams 5 to 8). Iron wire that is not protected in some manner will rust, because of the moisture in the air. To prevent rust taking place and destroying the metal, the iron is coated with another metal that will not rust. Iron wire can be coated with copper, which is deposited on the iron by electro-plating. If this copper coat is taken off by grinding or filing, it can be re-coated with copper by dipping the part to be coated in a copper-sulphate solution.

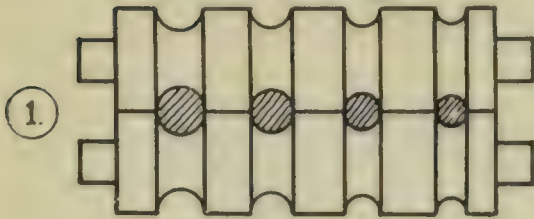
Copper Sulphate Solution (diagram 9). Take a few crystals of copper sulphate, or bluestone, and crush them into a powder. Put about one teaspoonful of the powder into $\frac{1}{2}$ pint of water; then add six drops of sulphuric acid to cut through the grease which may be on the metal to be coated. The iron must be ground, filed, or polished with abrasive cloth to remove any rust or iron oxide. Immerse the metal in the solution and take out to dry, and the copper coat will be seen on the metal.

Coating iron with tin or zinc in a molten bath. Before a metal can be coated by immersing in a molten bath of tin or zinc it must be *chemically clean*. To clean a ferrous metal (a metal containing iron or ferrite) immerse it in "killed spirits".

How to make "killed spirits" (zinc chloride). Take some hydrochloric acid (muriatic acid) and place it in a glass or porcelain vessel (diagram 10). Take the vessel outside in the fresh air or into a ventilator shaft; then add some granulated zinc (small flakes of zinc). A violent action takes place and a gas is given off called hydrogen. When the action ceases, while there is still some zinc present, the acid

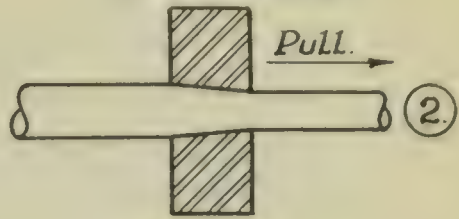
IRON WIRE (Continued)

Wire rolling.

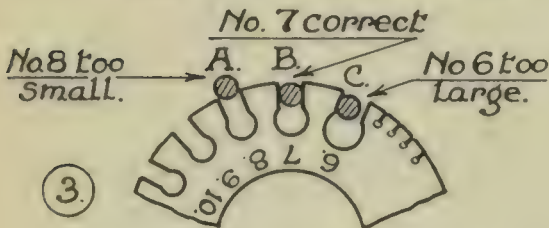


①

Wire drawing.

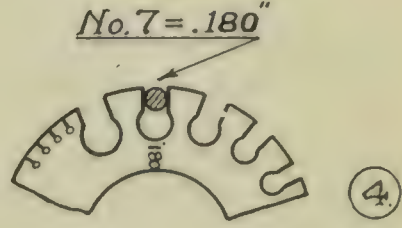


②



③

(front) Number size.



④

Decimal size. (back)

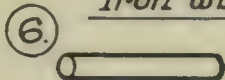
English standard wire gauge.

Iron wire finishes.



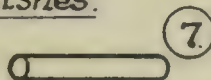
⑤

Black
annealed.



⑥

Coppered



⑦

Galvanized



⑧

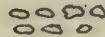
Japanned.

"Bluestone."



⑨ Copper sulphate.

zinc.

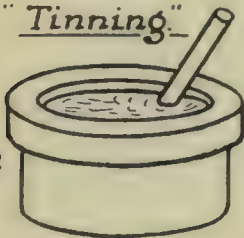


Hydrochloric
acid.

⑩ "Killed spirits."

"Tinning."

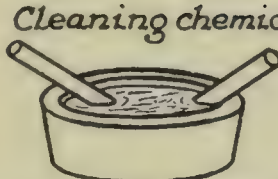
Molten
tin



⑪

Cleaning chemically. "Galvanizing."

"Killed spirits"



⑫

Molten
zinc.



⑬

is said to be "killed". Dilute this with an equal quantity of water and it is ready for use.

Tinning the iron. Dip the metal to be tin-coated or "tinned" into "killed spirits", contained in the lead dish (diagram 12). Then immerse it in the molten bath of tin and hold it there until the metal is heated through. Remove from the molten bath and wipe off the surplus metal with a dry cloth.

Galvanized iron (zinc-coated). This operation is similar to "tinning" except that the iron is dipped into molten zinc.

CUTTING METAL WITH HAND TOOLS

There are many tools which may be used to cut metal, and it is advisable for the beginner to select the best tool available for the purpose. The most important consideration is whether the metal to be cut is soft or hard. The greatest precaution must be taken for selecting tools to cut carbon tool steel, otherwise the cutting tools will be damaged and it will prove to be an expensive operation.

The cold chisel (diagram 1). This tool is made of carbon tool steel, or special alloy chisel steel, and has two levelled faces. For cutting off wire roughly the method shown in diagram (1) may be used, but it should be noticed that the chisel leaves the end of the wire bevelled. This can afterwards be corrected by grinding or filing. The chisel in diagram (2) has one bevelled face and can be used to cut off the end of wire square.

The blacksmith's hardie (diagram 3). This tool is made of carbon tool steel and fits in the anvil. It is used to nick metal either hot or cold or to cut it off. The metal to be cut is struck with the hammer and cut half way through. Then it is turned over and the opposite side is similarly cut. Care must be taken not to allow the hammer face to strike the edge of the hardie, otherwise both tools will be damaged. The hot and cold set used by blacksmiths to cut metal are illustrated on page 91.

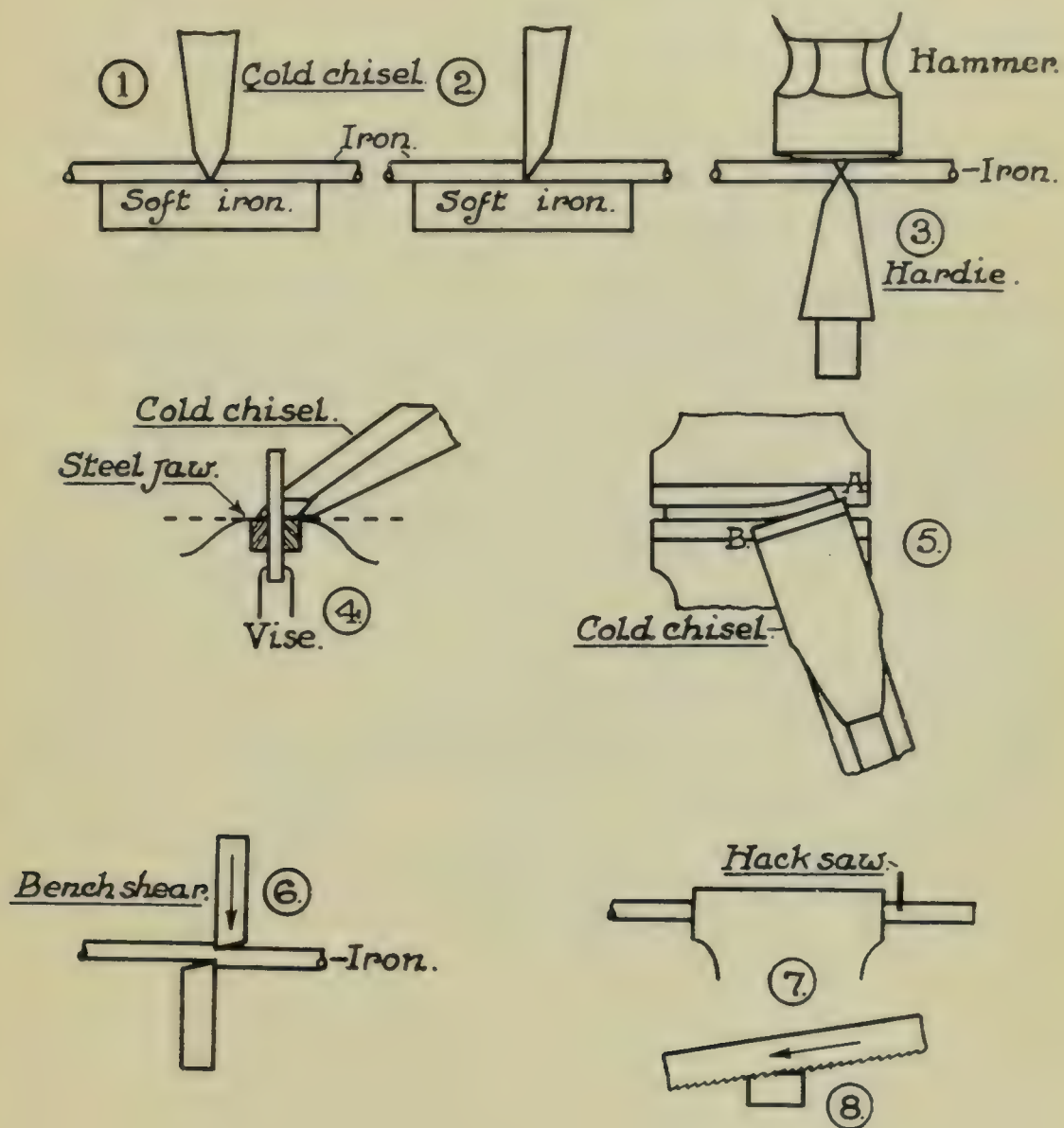
Cutting metal with the chisel and vise (diagrams 4 and 5). This method is very efficient and is a true shearing action if carried out correctly. The stationary vise jaw has a carbon tool steel face, which, also hardened and tempered, cuts against this edge of the vise to give the shear cut to the metal. It is very necessary to keep the two corners of the chisel, A and B, resting on both opposite top faces of the vise jaws. The lower face of the chisel should be kept horizontal. The waste metal should be above the vise and the line below the top of the vise.

Bench shears (diagram 6). This is the most effective tool for cutting metal stock that is soft (steel must never be cut on bench shears). The diagram illustrates the two shear blades of a bench shear which is designed for splitting plates, or for cutting band iron or iron rods within its capacity. It is usually designed with a good lever action to give the operator a distinct mechanical advantage. Hand shears work in a similar way.

Cutting stock with the hand back saw (diagrams 7 and 8). Care must be taken in using a hand back saw, otherwise the blade will be broken in cutting stock with it. If round stock is being cut, it must be held securely in a vise and the saw cut made about $\frac{1}{4}$ inch from the end of the vise jaws. If the stock is small, a fine tooth blade must be used so that the teeth will not hook into the corner of the metal.

Hack saw blades can be purchased "all hard", or soft backs with hard teeth, and beginners are advised to use the soft back as it is less likely to be broken.

CUTTING METAL WITH HAND TOOLS (Continued)



CUTTING METAL WITH HAND TOOLS (*Continued*)

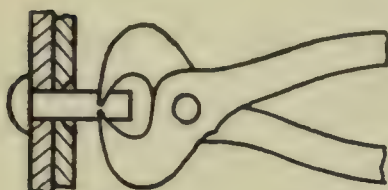
Cutting pliers (diagram 9). This is a very handy and efficient tool for cutting off small diameter iron wire, but must not be used for cutting off tool steel or the cutting edges will be ruined. The cutting nippers shown in diagram (10) are very suitable for cutting close up to a piece of metal such as illustrated.

Cutting off tool steel. The first thing the beginner must do with tool steel is to ascertain whether the steel is in the hardened or the annealed state (soft). This can be accomplished by testing with a file. If the file cuts the steel, it is soft. If the file teeth slip over the steel, it is hard. The only way to cut hardened steel is to use an abrasive wheel or grindstone. A cut-off wheel, shown in diagram (11), is specially designed for this purpose.

If such a wheel is not available, the corner of a grinding wheel may be used, as shown in diagram (12). After the steel is nicked all around, hold one part in the vise and break off the other part, giving it a blow with a hammer.

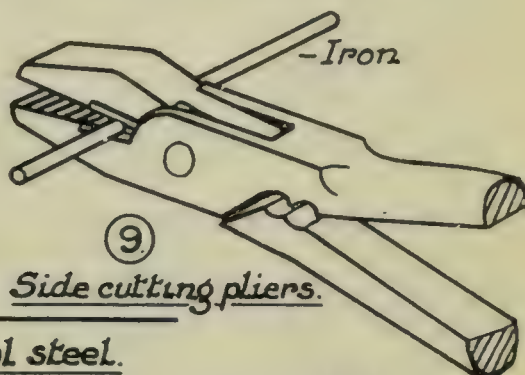
Annealed steel can be nicked hot if it is of large diameter (diagram 14). If of small diameter, it can be nicked with a triangular or three-square file and broken off the vise, as in diagram (13).

CUTTING METAL WITH HAND TOOLS (Continued)



⑩

End cutting nippers.



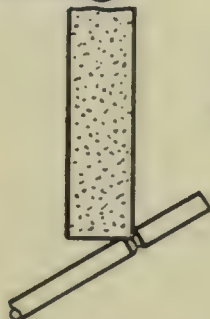
⑨

Side cutting pliers.

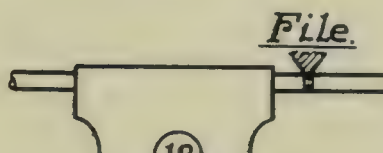
Grinding wheels ⑫



⑪

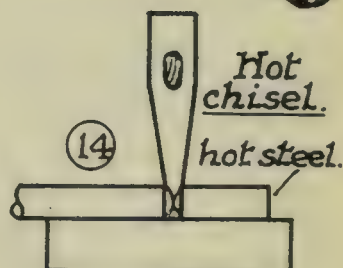


Cutting Tool steel.



⑬

File.



⑭

Hot chisel.

hot steel.

BENDING AND TWISTING METAL

Bending Jigs. Bending jigs, such as illustrated in diagrams (1 to 5), are very useful tools for making simple bends, particularly for iron wire. Jigs of this kind help the operator to produce duplicate bends with some degree of uniformity and control. Diagram (1) shows a jig with two pins protruding from a rectangular block of metal. The distance the pins are apart depends upon the size of the wire used. One pin is made lower than the other so that the wire may pass over the top of it to complete the circular bend. Diagram (4) shows a similar type of jig to diagram (1), except that it is made from one piece of round iron, bent when hot, and then held in the vise when used.

Bending an eye. The wire is placed in the space between the two pins, as shown in diagram 2A. The wire is turned in the direction of the arrow, producing stage 2B, a complete circle. It is then turned back against the smaller pin so that the eye is in the centre of the stem (diagram 2C). It will be noted that a short straight piece of wire is left over. This is then cut off square with a single-faced chisel, as shown in diagram (2), page 17, producing the finished eye (diagram 3).

Making a square bend. This operation may be accomplished by bending the wire in the vise, or with flat pliers. Diagram (5) shows a bending jig with slots cut on the top of the pins, into which the wire is placed and bent as shown.

Twisting wire. Diagram (6) shows a simple project used for lifting tacks or can lids. It is made from iron, but because the wire is twisted, it is quite strong. The "cold working" that the metal undergoes in twisting hardens the wire perceptibly, and the operator will note that the wire gets warm while being "worked" in this way. The force involved in twisting a metal is called "torsion".

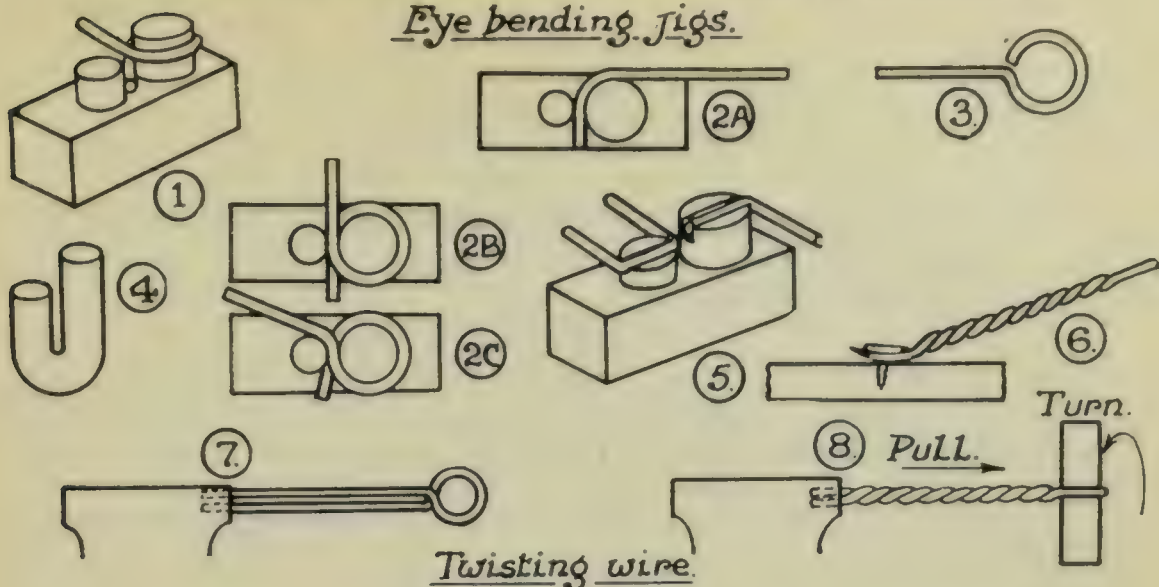
The first stage is to form an eye, the wire being bent back across the small pin. The wire is then held in the vise, ready to be twisted, as shown in diagram (7). A round metal rod of the size of the eye is placed through it, as shown in diagram (8), and the wire is put in "tension" or pulled, while the rod is rotated, as shown, to twist the wire.

A round-nosed plier. A round-nosed plier is a useful tool for forming a small eye. The wire is gripped between the nose of the pliers, and the pliers are then turned to form the eye.

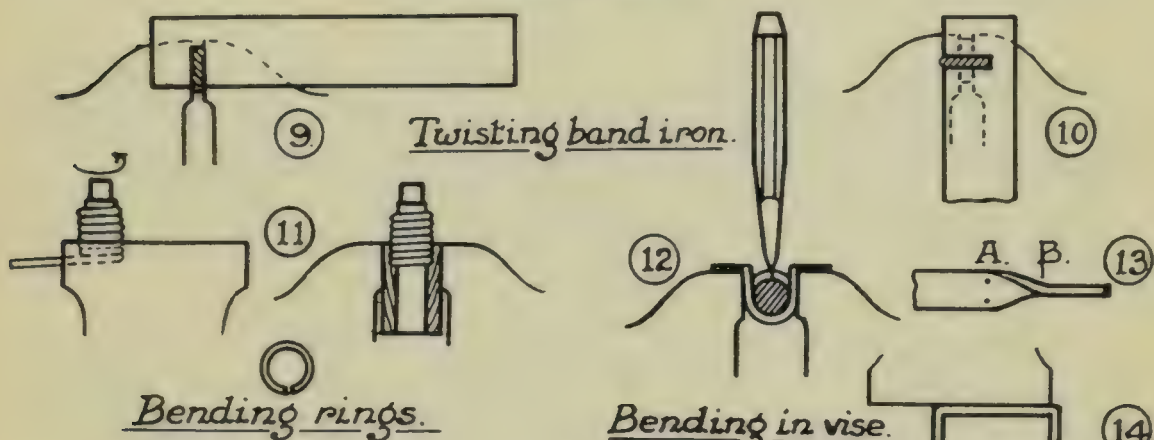
Bending rings. Occasionally it is necessary to form rings of metal wire. This can be accomplished simply by winding wire around a mandrel, or by turning a round mandrel while it is being squeezed between two blocks of wood in the vise. The wire is first passed through a hole in the mandrel and a tap wrench is fitted to the square shank of the mandrel to turn the metal, as shown in diagram (11). The coil of wire is then cut through, parallel to its axis, with a cold chisel on a soft iron mandrel held in the vise, as shown in diagram (12), producing a number of small iron rings.

BENDING AND TWISTING METALS (Continued)

Eye bending jigs.

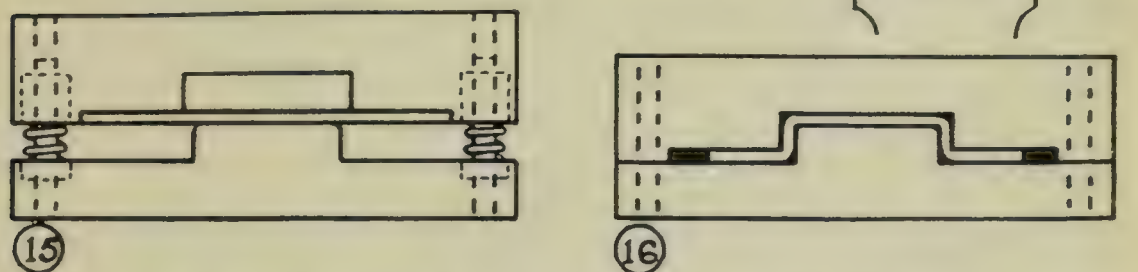


Twisting wire.



Bending rings.

Bending in vise.



Twisting band iron. A flat piece of metal with a slot cut into it is useful for this purpose. This tool, shown in diagram (9), fits over the edge of the metal and is used as a lever to twist the band iron while it is held in the vise. Diagram (9) shows the start, and diagram (10) the finish position of a right angle bend. It is necessary to allow sufficient space for the twist to take place, as shown from A to B (diagram 13). If such an allowance is not made, the metal will be cut or sheared off against the end of the vise jaws.

Bending band iron. Diagram (14) shows how band iron may be bent to a right angle bend in the vise, a block being used to finish the second bend. A jig, similar to the one shown in diagram (15), is useful for producing a uniform, accurate shape. The metal is placed between the two blocks of the jig and squeezed between the vise jaws, producing the finished shape, as shown in diagram (16).

HAMMERING METAL

If a piece of lead (diagram 1) is hammered on a metal block or anvil, the pupil can learn something about the properties of a metal and the effect of hammering it.

Start to hammer the lead from the centre, and hammer outward, so that the outside remains softer than the inside and will stretch. As the metal is hammered, it gets thinner and larger in area. If the blows are arranged uniformly over the surface of the square metal, it will be made into a larger square with slight rounding of the corners. It will be noticed that lead hardens only slightly by hammering, as it proves to be a malleable metal (diagram 2).

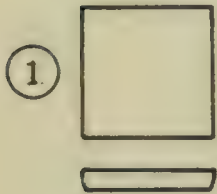
Rolling metal (diagram 3) produces far more uniform stretching of metal than hammering, and the hardness of the metal is approximately the same throughout because of the regular pressure of the rolls. The surface of rolled metal is a duplicate of the surface condition of the rolls; that is, smooth rolls produce a metal with a smooth surface.

Hammering to a Shoulder. Diagram (5) shows a piece of wire being flattened to a shoulder. The object of this is to spread the metal, making it wider and thinner. It is advisable to file a nick in the metal, as shown in diagram (4). This nick is placed against the edge of an anvil, or solid metal block, and the first blow is struck directly over it, as shown in diagram (5), producing the shape shown in diagram (6). The blows are then given towards the end of the wire in order, hardening the metal by successive blows so that it stretches or elongates along the line of least resistance, which is always towards the softer metal, producing the shape shown in diagram (8). Diagrams (4 and 7) show the effect of hammering a piece of wire. The wire after being hammered becomes longer, wider, thinner, and harder. This is sometimes called hardening iron by "cold working", and if overdone it will cause the metal to split.

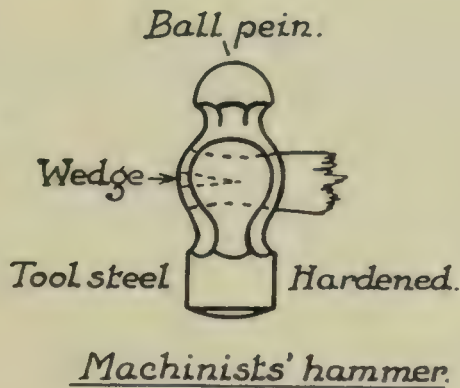
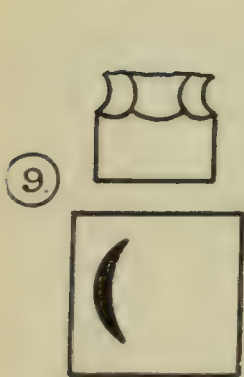
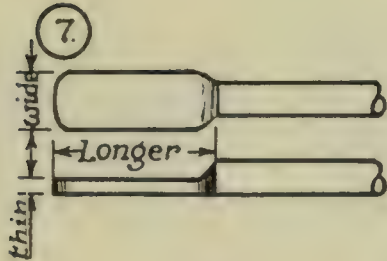
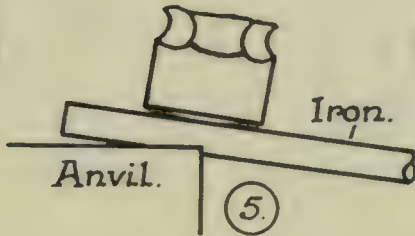
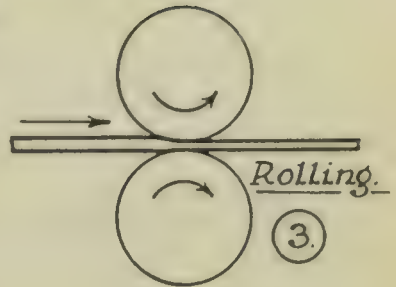
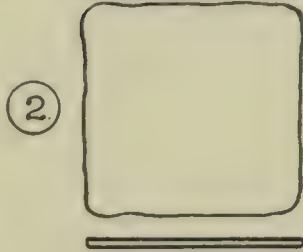
Use of the Hammer. Diagram (9) shows the kind of hammer mark left on a piece of metal struck with a hammer face that is perfectly flat. It is very difficult to strike the metal with a uniform blow if the face is perfectly flat, and so the face is usually made convex, as in diagram (10). This face readily produces a uniform blow on the metal with a slight concave indentation.

HAMMERING METAL

Lead casting.



Hammered lead.



Ball pein.

Wedge

Tool steel

Hardened.

Machinists' hammer.

HAMMERING METAL (*Continued*)

Diagrams (11 and 13) show the effect of hammering on one side only of a piece of metal, thus causing the metal to turn away from the hammer blows, that is, towards the side of the softer metal, which gives way under the pressure of the harder metal.

Diagram (12) shows that by a uniform distribution of hammer blows the metal is drawn out in a straight line and is of the same degree of hardness throughout.

Hammering metal hot (diagram 15). Hot iron becomes quite soft and spreads readily under the hammer blows. Usually thick metal is heated in a forge or furnace so that it can be forged with a hammer quickly to the shape required. In addition to this, hot-worked iron remains soft, in contrast to cold-worked metal, which becomes hard (diagram 14). By hammering metal hot the grain of the metal can be made fine. That is why steel is improved by hammering. This can easily be seen by examining the fracture of a metal before and after hammering hot, as shown in diagrams (16 and 18). If a piece of iron were hammered hot to shape (diagram 17), it would likely bend in use, while a similar piece of iron hammered cold would be harder and stiffer.

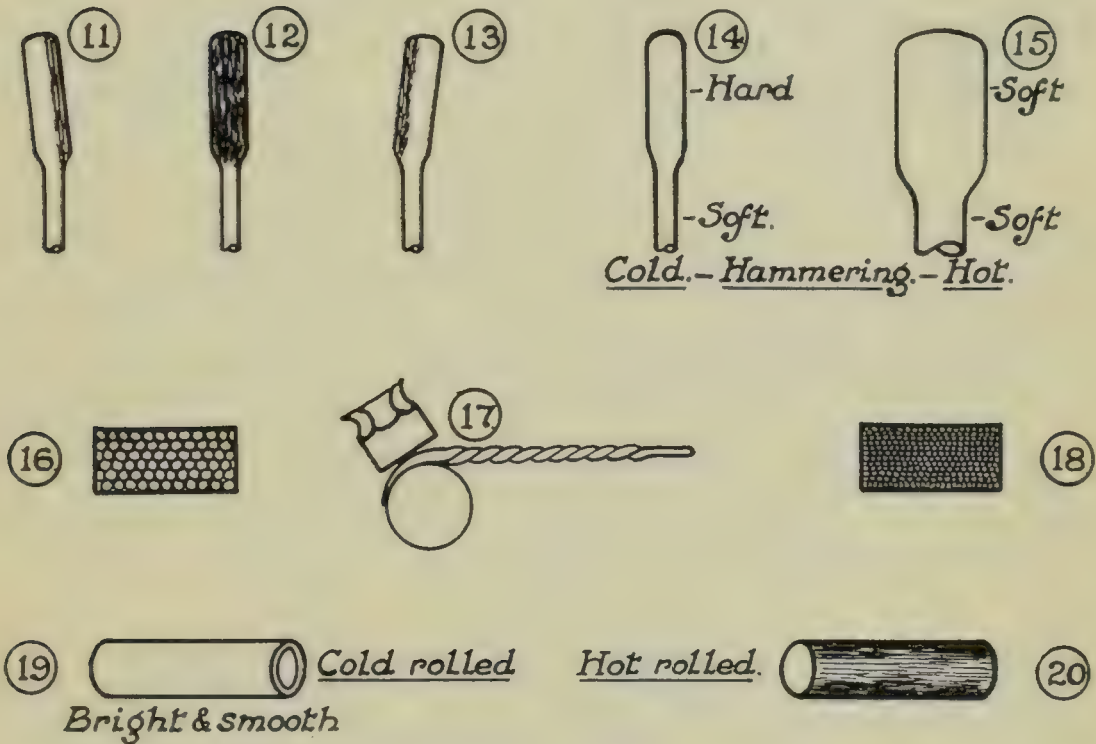
Cold-Rolled Shafting (diagram 19). Cold-rolled metal has a hard skin, due to cold rolling, as oxidation does not take place as in hot rolling. Its surface is bright, due to the condition of the smooth rolls used, and its core is soft and tough. Metal like this can be "used direct" in making machinery, because it is accurate as to size, is round, and has a hard-wearing surface.

Hot-Rolled Metal (diagram 20). This iron is uniformly soft, because it was finished rolled when hot and consequently a black rough scale formed on its surface (iron oxide). Such a metal must be machined before use, if required to fit accurately into some part of a machine. For ornamental or rough purposes the surface condition of the metal does not matter; in fact, its very roughness and lack of uniformity is considered part of its beauty in ornamental work.

Hammered Effects. Hammered effects are often given to iron work (as shown in diagrams 9, 10, 11), page 7, to add interest to the surface of the metal and to give contrast to an otherwise uniform surface.

Note: Be sure to examine a hammer to see that the wedge is fitted correctly. A loose hammer head is very dangerous.

HAMMERING METAL (Continued)



LAYING OUT METAL

Coating and scribing lines on hot rolled metal, or cast iron, or steel. A piece of black iron can be laid out by scribing lines on its surface with a sharp-pointed steel tool called a scriber, which is made of tool steel, hardened and tempered (diagram 1).

A hot-rolled piece of iron (diagram 2) is covered with a black scale (iron oxide), and when a scratch is made on its surface with a scriber, the line shows up bright in contrast to the black scale. The rough metal can also be coated by rubbing ordinary chalk over it, as shown in diagram (4). When lines are scribed on this surface, the scriber exposes the black scale in contrast with the chalk. Large surfaces of hot-rolled, or cast iron, or steel, are coated with whitening with a brush (diagram 3). The metal coated in this manner is allowed to dry, and then the lines are scribed on it (diagram 5).

Scribing lines in cold-rolled iron or steel (diagram 7). This metal has a bright surface, and although a newly scribed line makes a slight contrast, it is better to use one of the following methods.

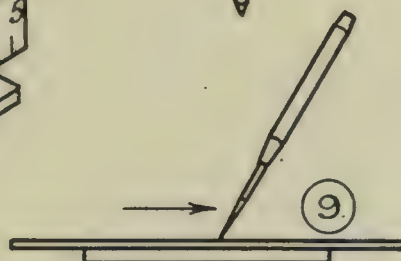
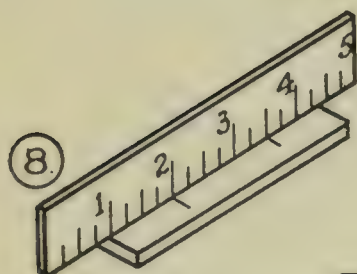
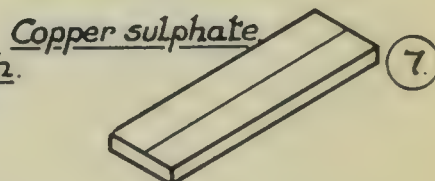
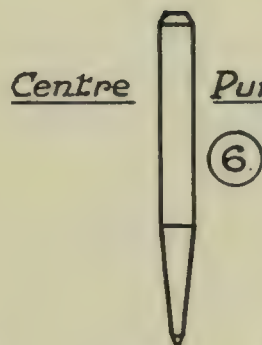
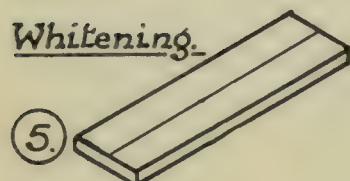
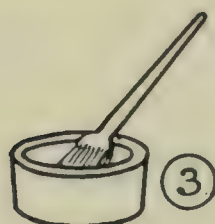
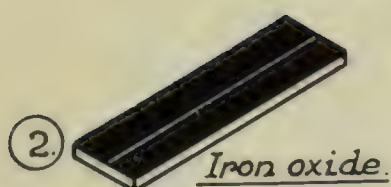
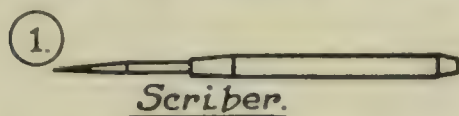
Coating the surface with copper sulphate (diagram 7). The bright ferrous metal (metal containing ferrite or iron) can be dipped in a copper-sulphate solution, or it can be applied to the surface of the metal with a brush. If the metal is heated gently till dry, a copper deposit will be formed. Lines are scribed on this coppered surface, exposing the bright iron, thus giving a good contrast.

Heating metal to blue. If a bright ferrous metal is heated, oxidation takes place and colours appear on its surface, ranging from light straw to purple and blue. When the surface of the metal is uniformly blue, the lines are scribed into it, giving a good contrast.

Measuring from the rule. Place the rule or scale on edge, as shown in diagram (8). Then pick off the measurement exactly with the serrated graduation on the scale.

Scribing lines. The scriber point must be placed close up to the edge of the rule, as in diagram (10), and the scriber moved along the rule in a trailing manner, as shown in diagram (9).

LAYING OUT METAL (Continued)



LAYING OUT METAL (*Continued*)

Squaring lines with the scriber (diagram 11). The scriber point is first placed on the location of the proposed line, and the square is moved up to it. The square must be pressed against the edge of the metal with the fingers and thumb pressing it at A and B; then the line can be scribed square.

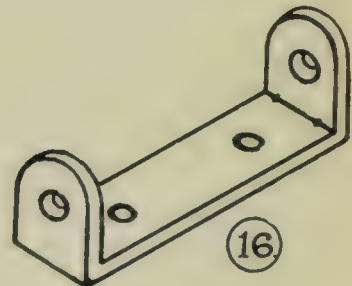
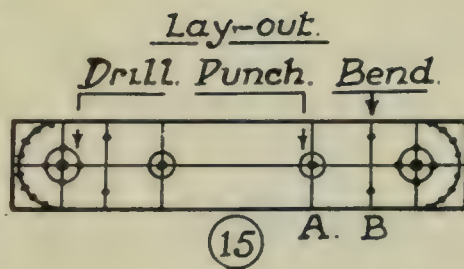
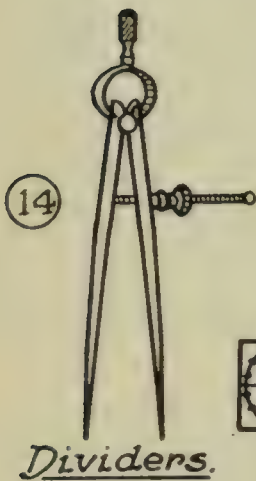
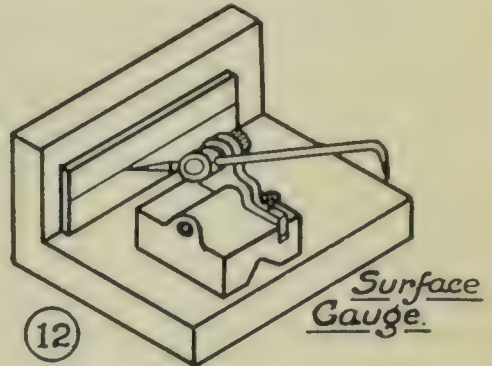
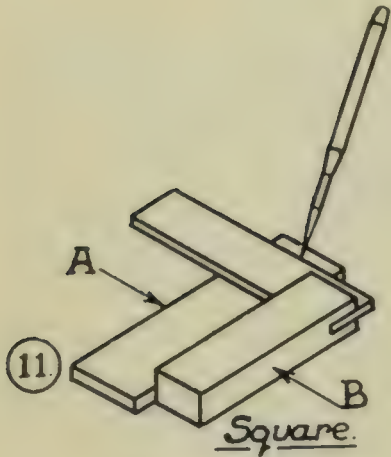
Scribing lines parallel with an edge (diagram 13). The herma-phrodite calipers can be used for this purpose, if the line is not too far from the edge. The bent leg of the caliper is placed against the edge of the metal, and the straight leg on the location of the proposed line. Then the tool is trailed along the work, producing a parallel line. Parallel lines can also be made by measuring an equal distance at two extreme points parallel to the edge, and joining the points.

A surface gauge (diagram 12) is set up on a surface plate in laying out metal. The edge of the metal to which the line is to be parallel also rests on the surface plate, so that when the surface gauge is moved on the plate, the scriber point marks a line parallel with the edge of the metal.

Laying out a piece of work. A simple piece of work to be carried out is illustrated in diagram (16). The stretch-out of this piece is shown in diagram (15), showing the layout of the metal. The circles are marked with a pair of dividers (diagram 14).

A centre punch (diagram 6). A centre punch is used to make a permanent centre dot in metal. A heavy centre dot is made at A so that the punch used to make the hole may have its centre point located in it before punching. Two dots are made at B to guide the operator in making a square bend. The hole to be drilled is located by five dots, a heavy one at the centre to guide the drill point, and four dots on the circle to check up, in order to see if the drill follows the correct location.

LAYING OUT METAL (*Continued*)



PUNCHING AND RIVETING METAL

Punching a hole in metal is a very suitable operation to provide a method of riveting metals together. It is much quicker than drilling holes and involves much less trouble, but it is only possible to punch comparatively thin metal. Thick metal, requiring deep holes, must be drilled. Before punching small work it is necessary to locate the centre of the punched hole with a centre punch, struck with a blow from a hammer, thus making a conical indention in the surface of the metal (diagram 1).

Methods of punching holes. For large work holes are punched with a machine called a "punch press". Small holes in metal are punched with a bench tool called a "bench punch", which usually operates on a lever principle, giving the operator a mechanical advantage. The bench punch consists of the lever device and the punch and die shown in section in diagram (4). The punch and die are both tapered back from their cutting edges to give clearance in punching metal, and both are made of tool steel, hardened and tempered. After the punch passes through the metal, the metal sticks to the punch; but as the punch is lifted out of the die, it passes through the stripper, which pushes the metal off the punch, allowing it to be taken out of the machine.

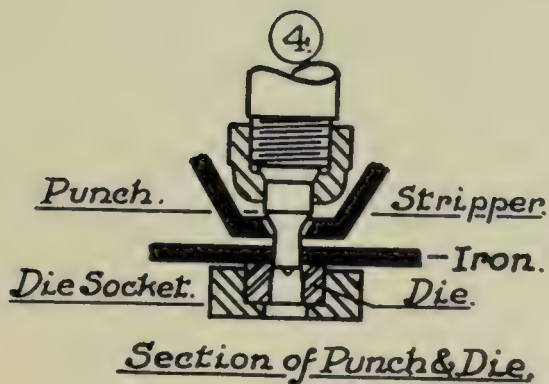
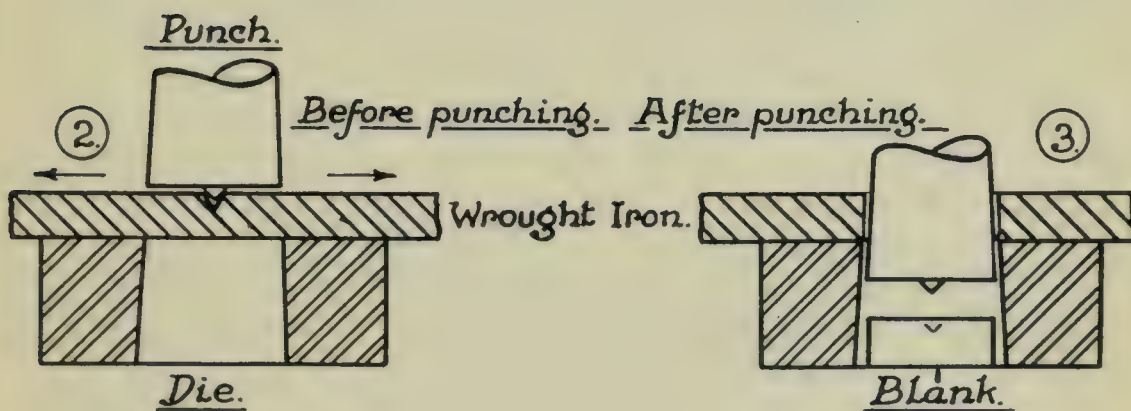
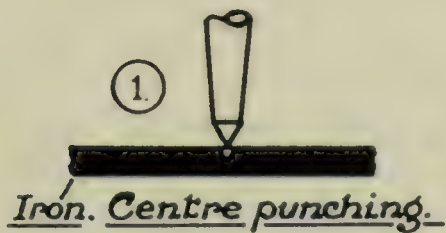
Locating the centre of the hole in the punch. Diagram (2) shows the punch about to start to punch a hole. It is very important for the operator to check up by feel in order to be sure that the point of the punch is firmly placed in the centre dot in the metal. This is accomplished by pulling the metal in the direction of the arrows, which proves that the point of the punch is locked in the centre dot and is correctly located.

Punching the hole. Diagram (3) shows the hole after punching. The waste piece of metal is dropping free through the die. You have probably already used a bench shear, which is a straight shear cutting tool, so that you can easily realize that a punch and die is really a circular shear cutting tool.

Fastening metals together by riveting. Rivets may be used to fasten metals together permanently; that is, it is understood before riveting that it will not be necessary to take the metals apart, otherwise some other fastening would be selected, such as bolts or cap screws.

Cold riveting. Cold riveting is usually carried out on small work; and soft iron, brass, or aluminum rivets are used according to the metal being riveted. The head of the rivet is formed by light hammer blows, which spread the metal but do not harden it, as heavy blows would do. Hammering causes the rivet to exert a pressure, which holds the parts to be riveted together.

PUNCHING AND RIVETING METAL (*Continued*)



PUNCHING AND RIVETING METAL (*Continued*)

Hot riveting. Hot riveting is carried out on large work, because the rivets are big and require heat before the metal is soft enough to spread. A pneumatic tool or air gun is used for this purpose, as it gives rapid powerful blows to the heated rivet to form the head.

In addition to the ordinary pressure given to a rivet, the rivet, while cooling, contracts and draws the plates closer together. Many examples of this can be seen in bridge building, ship building, and steel construction of large buildings.

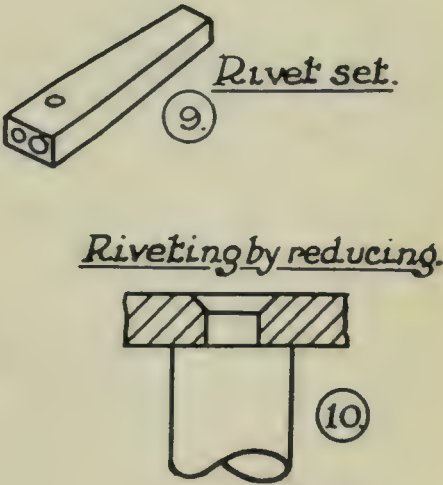
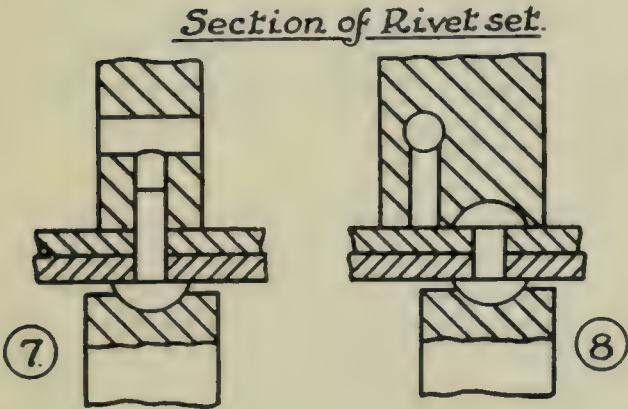
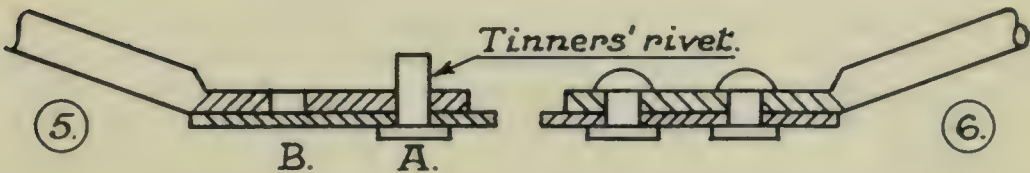
Riveting thin metal. Diagrams (5 and 6) show a piece of flattened wire being riveted to a piece of tin-plate or aluminum. A special rivet is used for this purpose, called a "tinnners' rivet". It has a large diameter and thin head, so that it will not protrude too far from the metal surface and interfere with the use of the work, such as would be the case in an ordinary kitchen utensil called a "slice". *Note:* Rivet "A" before punching or drilling "B".

The broad head of a tinnners' rivet distributes its pressure over a comparatively large area, which holds the thin plate securely and prevents it from being pulled through the thin metal.

Use of a rivet snap. Diagram (9) shows a rivet snap which is used for riveting. After the rivet is put through the punched holes of the plates to be riveted together, the snap is placed over the unfinished portion of the rivet and a blow is struck with a hammer which draws the plates and the rivet head together, as in diagram (7).

The concave recess in the snap (diagram 8) is then placed over the rivet and struck several blows until the soft metal of the rivet is forced into the recess of the snap, which forms the other head of the rivet and presses the plates permanently together.

PUNCHING AND RIVETING METAL (Continued)



IRON WORK

Iron is a most important and much used metal and is not very costly. There are certain qualities possessed by wrought iron that give it great superiority over cast iron, although cast iron is much used when articles are to take a required form. Cast iron is very brittle, but it is strong in compression, while wrought iron has a fibrous texture which makes it tough, and enables one to bend it into various shapes without breaking. Wrought iron is also malleable; that is, it can be drawn or flattened out into many forms, particularly when heated. Its ductility allows it to be formed by drawing it out into fine wire or to be rolled out into sheets. Another valuable quality iron has is its ability to be welded.

Many ornamental and useful projects can be made of iron; and in recent years it has been used to beautify the interior and exterior of homes. The pupil will be able to make very interesting objects by bending, hammering, twisting, and riveting iron.

Rust. One of the greatest drawbacks to iron is its natural tendency to rust. Acids and water do a great deal to hasten the tendency. Rusting of iron proceeds very rapidly when once it has commenced, and it has been proved that rust creates more rust.

Protection of iron from rust. The accompanying sketches show many ways in which iron may be protected from rust. Paints are the commonest and cheapest form of protection. A film or coating is given to the metal to exclude air and the moisture and acid fumes that are usually in it. This method is seldom entirely successful, as paints chip or wear off and have to be renewed. The most important thing about paint protection is the paint base that is mixed with the linseed oil in making the paint. Red lead is regarded as one of the best substances for this purpose.

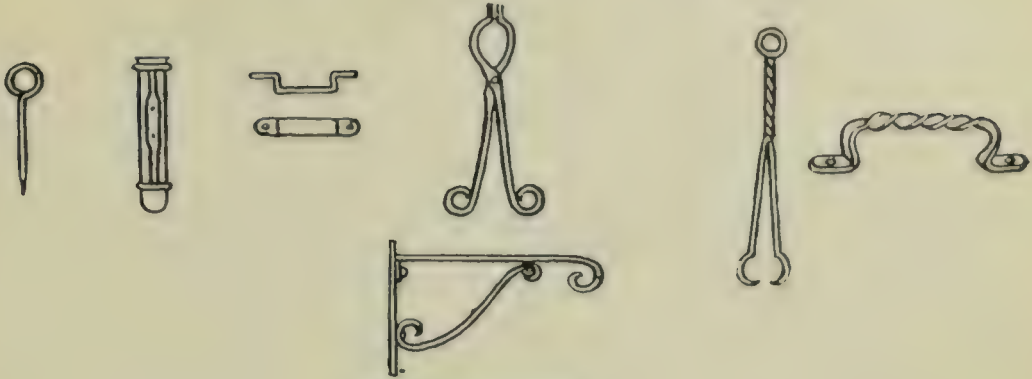
Protection of iron metal deposit. Other metals are frequently used to protect iron from rust. The metals used are not affected by rust or they form their own protection from rust. Tin does not protect as well as zinc, but as zinc forms poisonous compounds it cannot be used for food containers. Large buildings to-day have the steel and iron work covered with cement. This practically acts as a paint and prevents corrosion, but time alone will tell how permanent it is.

Methods of protecting iron from rust. (1) Painting; (2) Dipping into molten metal. Examples, tin plate and galvanized iron (zinc coated); (3) Electro-plating with zinc, copper, or nickel.

Iron products. The accompanying sheet shows a few objects made of iron, but the pupil can see hundreds more by looking for them in almost every line of business. It will be discovered that iron cannot be hardened and tempered. It may be case-hardened, so that cutting-tools and articles requiring spring and temper must be made of steel.

Fastenings for iron. Iron parts can be fastened together in any of the ways shown in the accompanying sketches. Soldering, brazing, welding, and riveting are permanent fastenings, while screwed and bolted fastenings may be taken apart and put together again.

IRON WORK (Continued)



PROJECTS.



Rust.



Lacquer.



Paint.



Enamel.



Red lead.



Duco.



Bronze.



Aluminum
paint.



Copper sulphate.



Nickel
plate.



Tinned.



Tin.



Zinc coated.



Zinc.



Cement.



Enamel
ware.

RUST PREVENTION. IRON COATINGS.



Rivet.



Washer.



Bolt.



Screen.



Wire.



Band.



Bar.



Rod.



Nail.



Angle iron.

PRODUCTS.



Soldered.



Brazed.



Welded.



Spot-weld.



Riveted.



Screwed.



Bolted.



Set
Screw.

FASTENINGS.

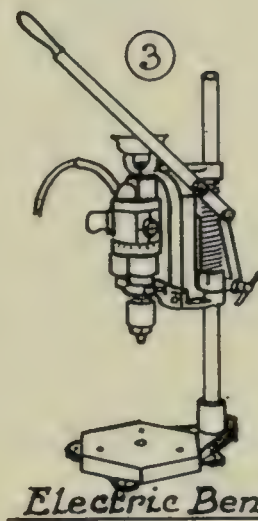
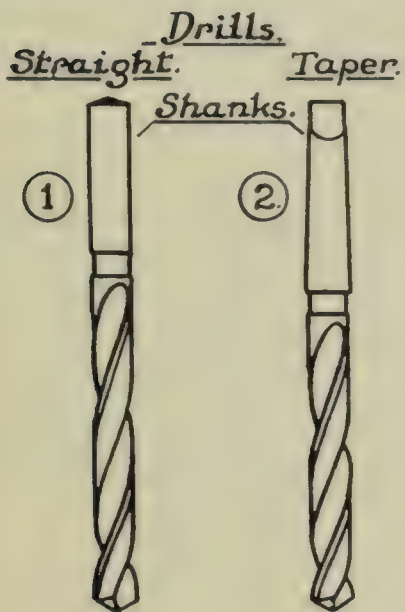
DRILLING AND COUNTERSINKING

Drilling devices. Most beginners first start to use drills with hand or bench drills. A hand drill is suitable only for drilling small holes in thin metal. A breast drill, hand-operated, is used in a manner similar to that used in the case of a hand drill, but for holes of larger size. An electric drill can also be used by hand and it is a most efficient tool. The bench drill, hand-powered, is safe to use, but it is very slow. An electric bench drill, similar to the one illustrated in diagram (3), is a very efficient and convenient tool. It is fastened rigidly to the bench and is operated by a lever action which provides plenty of pressure for average small work. Large work, requiring large diameter holes, is drilled on a power-driven drill press.

Holding work for drilling. One cannot emphasize too strongly the danger of using an electric or any other drill unless provision is made to hold the work securely. The writer has had many sad experiences with young boys using drills for the first time, because they do not realize the danger of the drill breaking through the metal being drilled, and "grabbing" the metal (diagram 8, page 39), which, if held in the operator's hand, turns quickly, and causes injury to the hand in addition to bending or breaking the drill. The holding device must be fastened securely to the base or table of the drilling machine. An ordinary tool-maker's vise is sometimes used to hold work, but for thin metal the device designed by the writer has proved very effective and safe. Diagram (6) shows how the pressure is exerted on the work. For one lb. of pressure turning the wing nut, 150 lbs. is exerted on the work, due to the mechanical advantage of the hold-down device. The wood to which the device is bolted is also held to the metal base of the machine, which provides a suitable coefficient of friction to hold the metal under the pressure.

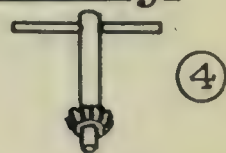
Types of drills. Two types of drills are commonly used by beginners. Straight shank drills (diagram 1) are used for holes under $\frac{1}{2}$ inch and can be used in electric drill chucks; but larger holes should be drilled on a drill press with a drill having a taper shank and tang which fit into the drill spindle to give a positive drive (diagram 2). The straight shank drill is driven by friction and if allowed to slip in the drill chuck (diagram 5) it cuts the shank away, which then tends to make the drill "run out of true". Do not start the machine until the chuck key (diagram 4) is removed, otherwise there is danger of the operator being cut.

DRILLING AND COUNTERSINKING (Continued)

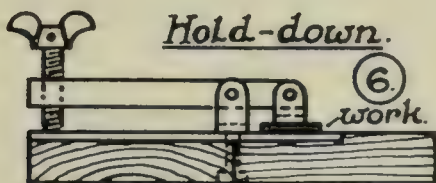


Electric Bench Drill.

Chuck key.



Drill chuck.



DRILLING AND COUNTERSINKING (*Continued*)

Drilling work held in the vise. Diagram (8) shows a piece of metal being drilled while held in a vise. A piece of wood can be used to support the metal and hold it at right angles to the axis of the drill. The wood must be smaller in width than the metal so that the vise grips the metal only. Metal parallels can also be used, as shown in diagrams (11 and 12).

Drilling a hole. The metal must first be laid out, as in diagram (10), with a very heavy dot to start the drill in its true axial position. The four outside dots show the size of the hole required, but they are also put there so that the operator can see if the drill is drilling concentric with the guide dots, as in diagram (7). If the drill is not drilling true, cut a groove with a round-nosed chisel to "pull" the drill over into its proper location, as shown in diagram (9). As the drill point is about to break through the metal, release the pressure somewhat, otherwise it will grab the broken edges of the hole and break the drill, if it is of small diameter.

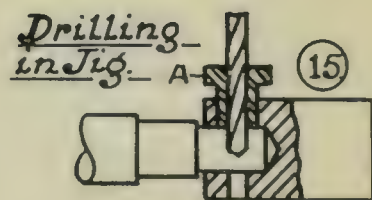
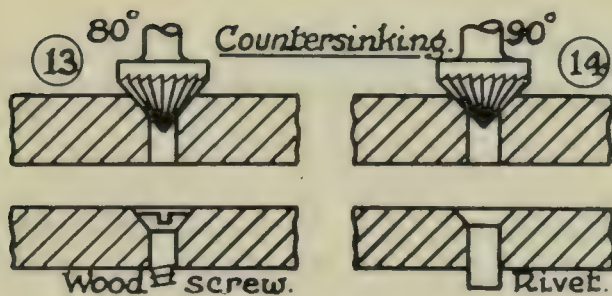
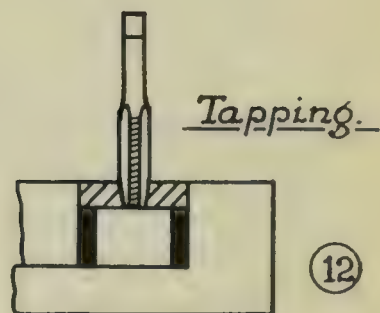
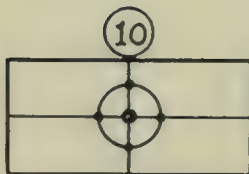
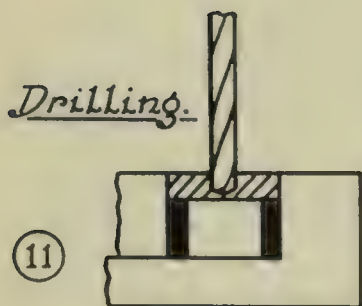
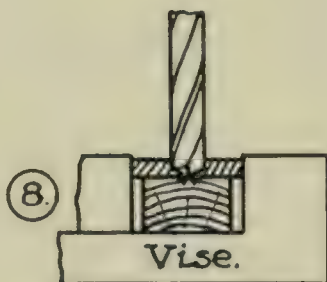
Drilling for tapping (diagram 11). The tap-drill size must first be obtained from a tap-drill size table (page 108).

Example: A $\frac{3}{8}$ "-16 U.S. Standard tap requires a $\frac{5}{16}$ " hole drilled into the metal before tapping.

Drill Sets.

- (1). Straight shank or Jobbers' drills: $\frac{1}{64}$ " to $\frac{1}{2}$ " by 64ths".
- (2). Number sizes: No. 1 (.228" diameter) to No. 80 (.0135" diameter).
- (3). Letter sizes: A (.234" diameter) to Z (.413" diameter).

DRILLING AND COUNTERSINKING (*Continued*)



OBJECTIVE TEST: IRON

1. Iron (can) or (cannot) be hardened like steel.
2. The common objection to the use of iron is its tendency to..... when exposed to the air.
3. The commonest way to prevent iron from destruction is to protect it by.....
4. The most reliable base for paint for use on iron is.....
5. The rust of some other metals is a protection from further rust, but corrosion of iron causes further.....
6. Another name for rust is.....
7. Iron used for food containers and utensils is usually coated with.....
8. Iron used for pails is usually coated with the metal..... and is known as.....
9. Iron and steel work in concrete buildings is coated with....., as a protection against rust.
10. A copper surface can readily be given to iron by dipping it in a..... solution.
11. Rivets are made of iron because it is a..... metal.
12. Cans for canned goods are made of a metal called....., which is sheet....., coated with a thin layer of.....
13. Iron can be hardened on the outside by a process called.....
14. Iron parts can be fastened together permanently by the following methods: 1.....; 2.....; 3.....; 4.....; 5.....
15. Iron parts which may have to be taken apart are fastened by the following methods: 1.....; 2.....
16. Sketch a piece of band iron after laying out: (a) Previous to drilling a hole, (b) Previous to punching a hole.
17. How can you "carburize" iron?
18. How can you "case-harden" iron?
19. What is the effect on iron of hammering it: (a) when cold? (b) when hot?
20. Make a list of six laying out tools, and state the uses of each.
21. How can duplicate bends be made in iron? Illustrate your answer with a sketch.
22. Sketch two sections of a punch and die, punching band iron: (a) commencing to punch the hole, (b) after the hole is punched.
23. Sketch in section a round head rivet joint, showing two pieces of band iron riveted together.
24. What length of round iron, $\frac{1}{4}$ inch diameter, would be required to make a ring 5 inches outside diameter?
25. Sketch part of a wire gauge to show how wire is measured.

IRON PROJECTS



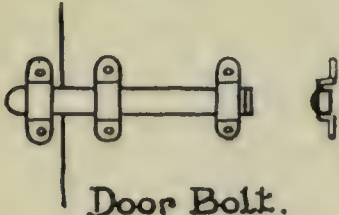
Tack Lifter.



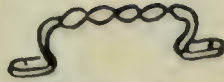
Tool Rack.



Door Fastener.



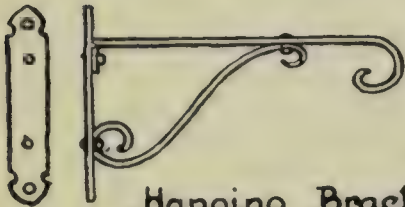
Door Bolt.



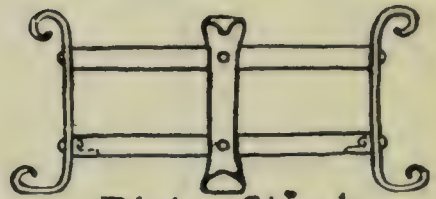
Handle.



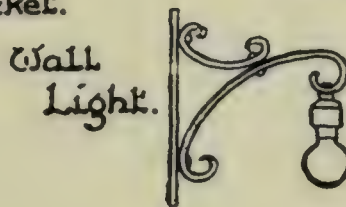
Foot Scraper.



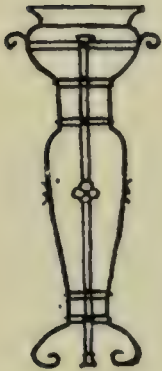
Hanging Bracket.



Dish Stand.



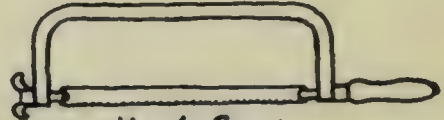
Wall Light.



Jardinière



Stand Lamp.



Hack Saw



Box.

Angle
Iron.

26. Explain how you would re-tin a piece of iron wire.
27. Name four common methods of protecting iron wire from rust.
28. State four tools used for cutting iron.
29. What are the differences between a hot-rolled mild steel and a cold-rolled mild steel?
30. Show by a sketch how you would support a piece of $\frac{1}{4}$ inch thick flat iron, while being drilled in a vise with a bench drill.
31. What is the disadvantage of a constant speed electric bench drill? What are its advantages?
32. What are the advantages of using the following: (a) A double-cut file? (b) A single-cut file? (c) Abrasive cloth?

ETCHING

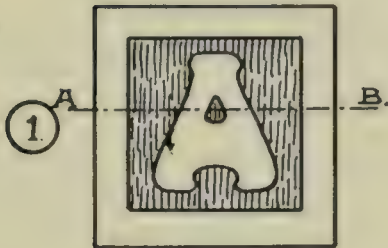
Etching a metal offers very interesting possibilities to the beginner in metal-work. It provides a means of decorating metal projects and enables one to produce articles of utility. To those who are artistically inclined it offers real enjoyment in the application of their drawing and painting ability. Thus far, the pupil has operated on metal with various cutting tools to remove some portion, but in etching, metal is removed by means of acid, that is, a chemical action takes place. One part of the metal is protected by a "resist" while the exposed metal is acted upon by the acid. Diagram (1) shows one method of etching, where a "resist" is painted on the metal for the border and the letter. The shaded part is eaten away by the acid. Diagram (2) shows how a border and the letter are obtained by etching them in to the metal, as shown by the shaded portion. The sections beneath each diagram, (1) and (2), show clearly the parts that remain intact and the parts eaten away.

Methods of copying the design on the metal. *Method 1* (diagram 3): After the metal is polished and holes are punched (if necessary), the surface of the metal is cleaned off with gasoline. The design prepared on a piece of paper is placed over the plate, with a piece of carbon paper between them. The outline is gone over with a pencil, which leaves a carbon copy on the metal.

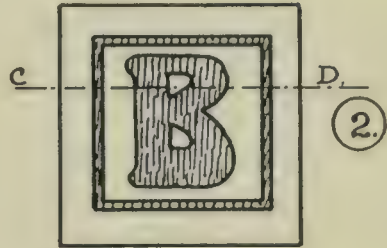
Method 2: A wax "resist" can be prepared, consisting of beeswax, two parts, black pitch, two parts, asphaltum, three parts, contained in a piece of cotton cloth. After the metal is polished, it is heated sufficiently to melt the wax. When there is sufficient wax on the metal, heat it again gently all over the surface; then allow the metal to cool in a level position. Place the design on the paper over the wax surface and go over the outline with a pencil, which leaves an impression on the soft wax. A scriber can then be used to cut through the outline, exposing the bright metal. Then the parts to be etched must have the wax scraped away to expose the metal to the acid.

Painting on the "resist". Diagram (4) shows the metal being coated with a "resist", which is usually black asphaltum paint. It is well to have two small receptacles, one for the black asphaltum, and one for a little turpentine, which is necessary to thin the paint to the correct consistency so that it may be applied smoothly with the brush. The design is carefully painted on within the carbon copy lines; and after the back and edges of the metal have been painted with the "resist", it is hung up in a slightly warm stove to dry (diagram 5).

ETCHING (Continued)



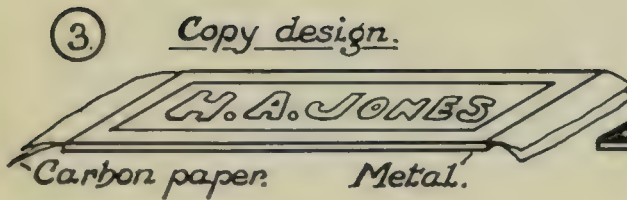
Section A.B. 



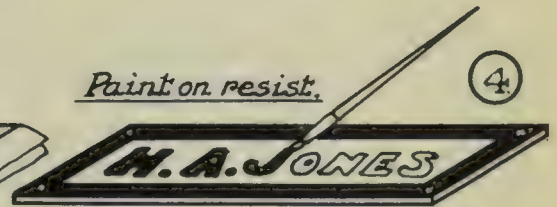
 Section C.D.

Design left standing.

Design eaten down.

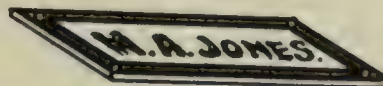


Turpentine.—



 Black Asphaltum.

(5) Stove.



ETCHING (*Continued*)

Immersing metal in etching solution. When the metal is thoroughly dry, it is suspended in the etching bath, consisting of nitric acid, one part, water, three parts, for copper or brass.

When mixing the acid and the water, *place the water in the jar first*, then add the acid, otherwise the acid will boil over and burn the operator. Sometimes it is convenient to use a flat glass, porcelain, or lead dish for an etching bath so that the work is horizontal.

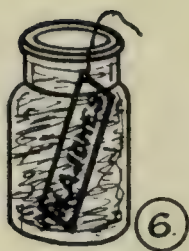
A gentle action is necessary to produce good etching. If the solution is too strong, large bubbles will be given off, and unless this solution is weakened, the work will be spoilt by stripping the "resist". If no bubbles are given off, warm the solution gently, or add a few drops of acid, to make the solution slightly stronger.

The time required will depend upon the depth required and the condition of the etching bath. When the metal is cut to sufficient depth, it should be removed and washed under the tap (diagram 8), and then it should be dried in saw-dust.

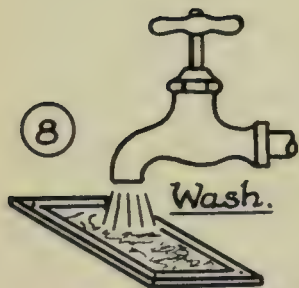
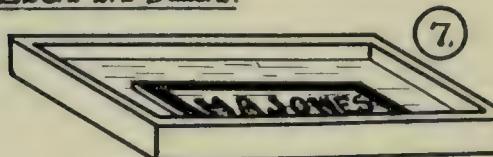
Colouring or oxidising the etched metal. It is necessary to have contrast in etched work to show up the etched surfaces. To do this a solution is prepared. For copper, a solution of potassium sulphide is suitable. Use about one cubic inch of potassium sulphide to one pint of water, and add one teaspoonful of ammonia. When the solution is properly mixed, immerse the etched plate in the bath (diagram 9). The "resist" is still on the metal, so that the colouring solution oxidises the etched part only. Remove the etched metal from the bath and stove gently till dry.

Removing the "resist". Soak the plate in a dish of gasoline; then wipe off the "resist" (diagram 10) with a cloth, exposing the original bright surface of the metal from beneath the "resist", in contrast to the oxidised portion that has been etched. To preserve the polish of the metal it should now be lacquered (diagram 11).

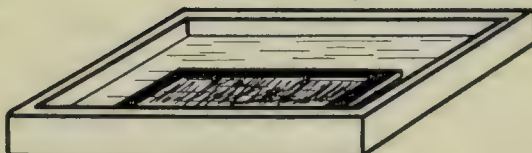
ETCHING (Continued)



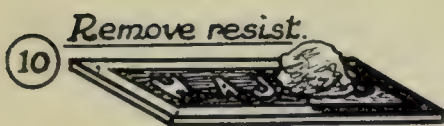
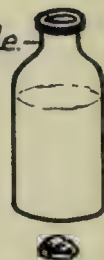
Etch in bath.



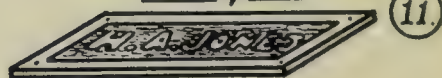
9 Coloring solution.



Potassium sulphide.



Lacquer.



DESIGNING A COPPER TRAY WITH RAISED EDGE

It is necessary for a beginner to realize that "design" does not necessarily mean "ornament", and that the relations of the measurements of a project have an important place in its design. The beginner usually makes the mistake of putting too much ornament on an object, thinking to make it attractive. Beautiful objects are usually very simple and show "good taste", so that the pupil must try by observation to produce artistic projects, which he will always enjoy looking at.

The Outline. The common primary shapes are the square, the rectangle, the circle, the triangle, the hexagon, the octagon, and the ellipse. These shapes, however, may be improved upon by combining one with another, or by slight changes in the primary shape.

Example: The accompanying sketch shows a triangular shape with rounded corners. This adds variety to the outline and suggests that the sharp corners of the triangle have been rounded off for convenience in use. A primary rectangular shape is also shown with some combined features of the ellipse. The eye feels that it is attracted to follow this outline all around, whereas the circle is regular and has not the same appeal.

Mass. The proportion of the mass is shown in contrast in the diagram sheet. It may be too small, too large, or too regular. An attempt should be made to obtain proportions that seem to give balance to the finished article, such as is shown in the proportion of 5, 8, and 5, in the diagram.

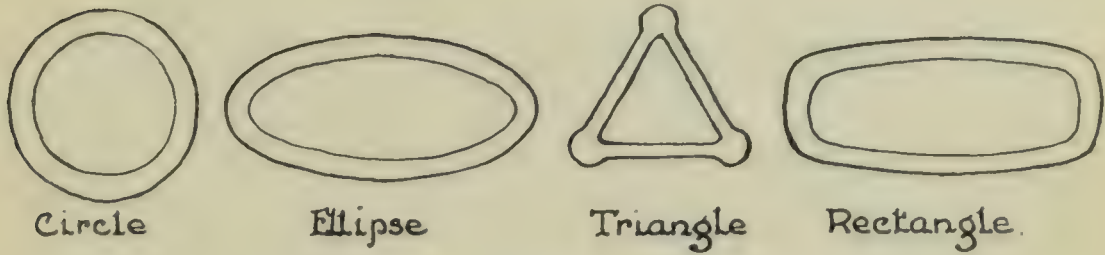
Primary Division of the Mass. The ornament applied to the mass will probably require some primary division. The illustrations show some divisions, and directly beneath each one is the ornament belonging to it. It should be remembered that ornament must be governed by environment; that is, if the tray is to be placed in a room on a table, it will seem very small in comparison, and only large masses will show to the casual observer. It is, therefore, advisable to bring out simple broad surfaces in relief, as fine detail will probably not be noticed, and the work required to carry it out will not prove worth while.

Method of Ornamenting Copper. A liner or tracer, shown on page 5, can be used to trace an outline, but a matting tool is a much easier tool for the beginner to use. By matting around a circle, for example, the metal is hardened where the tool is used, and the soft copper in the centre "raises", giving a slight relief. If the outer part of the design is hammered or punched, the hammered effect shows up the centre ornament in contrast.

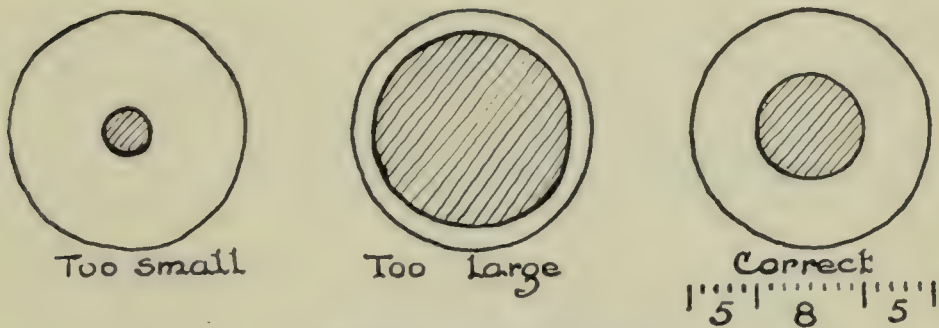
When the copper tray is coloured, the relief can be brought out with beautiful effect by polishing to bring out the high lights.

DESIGNING A COPPER TRAY WITH RAISED EDGE (Continued)

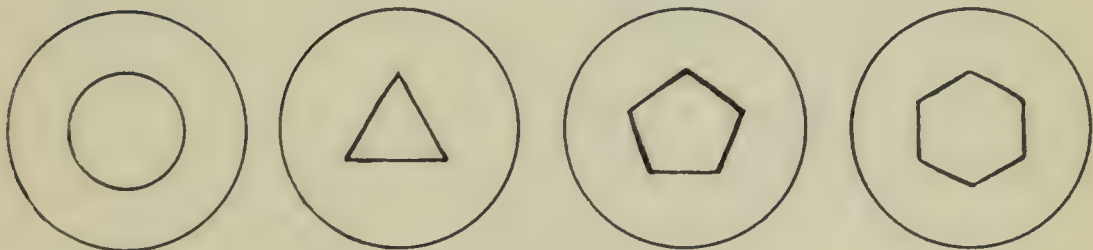
OUTLINE.



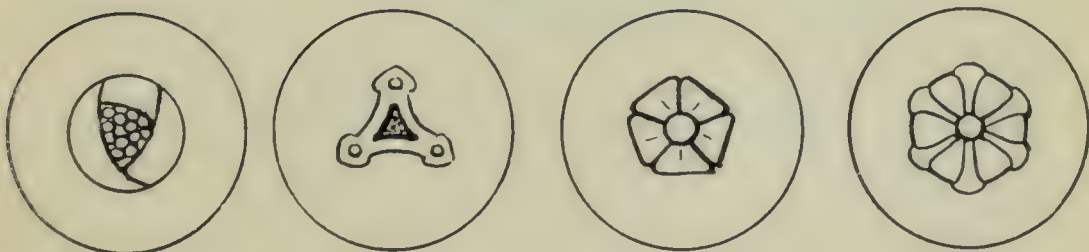
MASS



PRIMARY DIVISION.



DECORATION.



MAKING A ROUND COPPER TRAY

Annealing Copper. After the round blank has been cut from the sheet of copper with hand shears, it is advisable to anneal it to make it quite soft before starting to raise the edge.

The copper is heated to a pink heat and plunged into a pickle quenching bath, which leaves the surface of the copper clean. If the pickle bath were not used to quench the copper, a black scale (copper oxide) would cover the surface of the metal.

Raising a Round Copper Tray. Making a round copper tray is a raising operation, and as the edge is raised, the metal wrinkles. In other words, the edge or circumference of the blank must conform to a smaller diameter and circumference.

At first, the metal wrinkles to do this, but the wrinkles must be taken out to leave a smooth form on the raised portion.

It is necessary to stretch the metal to reduce the diameter and take out the wrinkles, just as a piece of rubber tubing, when stretched, reduces in diameter.

Method of Raising. A wood block is gouged on the top edge to suit the curvature and form of the tray. It is then held securely in the vise and the annealed copper blank is held so that it rests on the two corners of the gouged form of the wood. If a ball pein hammer is used to strike a blow between these points of support, the metal will be forced into the form and wrinkle. This is the first stage of the operation.

The tray should then be inverted on a hammering block and the bottom "trued" with a hammer. At the same time, the tray should be checked for circular form.

The wrinkles can then be taken out by hammering from the centre of the tray outward, by stretching the metal with hammer blows into the hardwood block until the wrinkles vanish at the outside edge.

Sinking the Tray in a Form. To do this, it is necessary to locate the metal concentric with the recess by the use of three or four nails. Then the annealed metal is hammered in spiral fashion, by starting at the centre, and hammering around until the outside is reached. It is important at this stage to realize that the outside edge must be kept soft to allow it to stretch. If the outside edge were hammered first, it would harden under the blows, and then, if the centre were hammered, the metal could not stretch and therefore it would buckle.

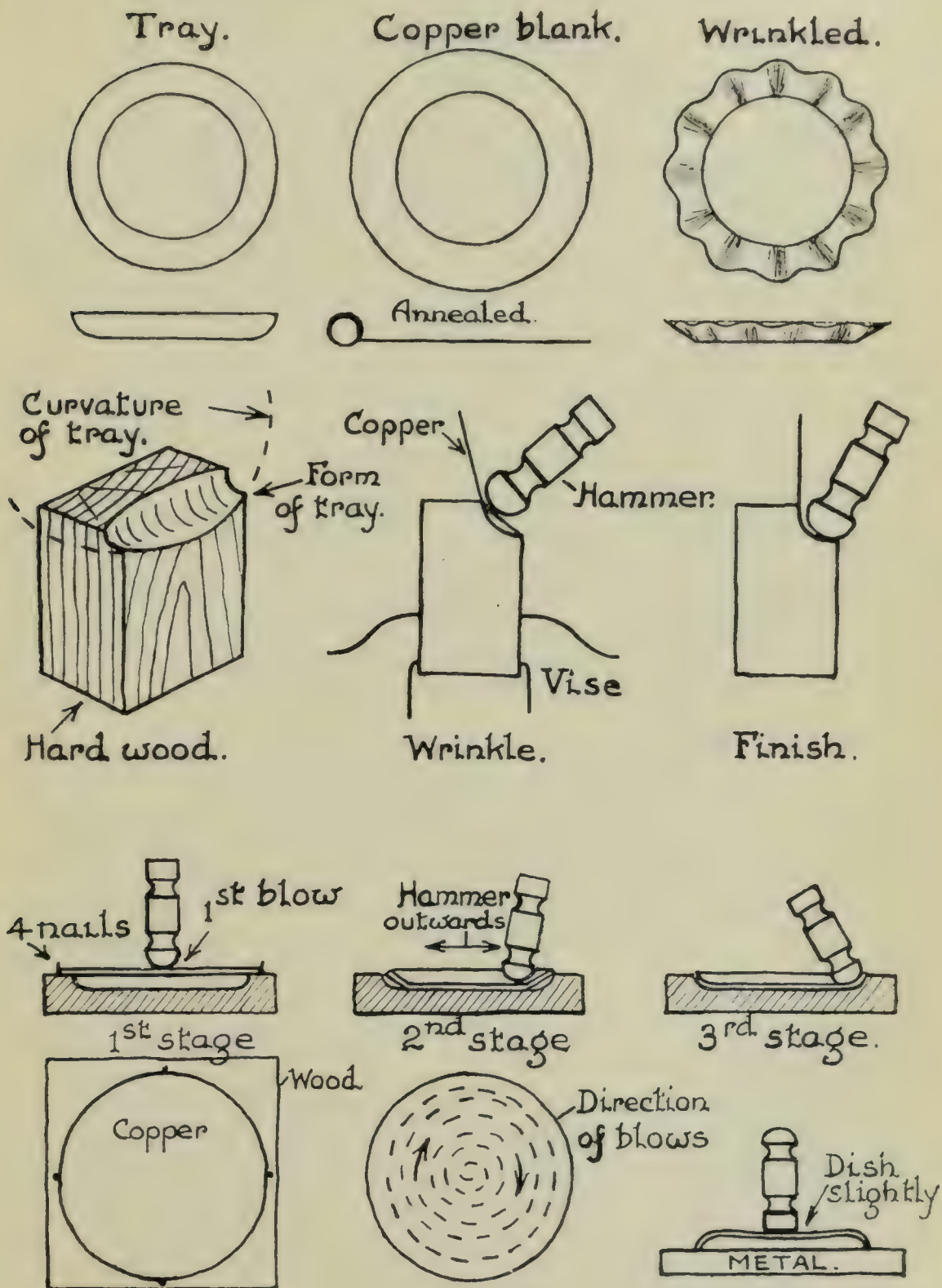
After the edge is raised sufficiently, the tray is turned over with its edge on a metal block and the bottom dished so that the tray will rest on its outer edge, when used, and remain steady.

The edge of a tray may be turned over a rounded metal stake with a hammer, but it is much easier to raise an edge when the metal is supported at two points while the hammer blows strike between.

Matting. The centre of the tray can be ornamented, as shown in the design lesson, pages 46 and 47. This can be carried out in a simple fashion by means of a matting tool or liner (see pages 4 and 5).

Note: See pages 50 and 51 for Polishing, Cleaning, Colouring, and Finishing Copper.

MAKING A ROUND COPPER TRAY (Continued)



POLISHING, COLOURING, AND FINISHING COPPER

When copper is exposed, it corrodes slightly, on account of the action of the constituents of the air and the water. This thin scale, called "copper oxide", is a protection for the copper against further corrosion. Copper oxide is a black film on the metal and does not look attractive. Consequently, it is better to polish the metal, or to give it some colour that improves its appearance.

Polishing. *Steel wool* can be obtained in various degrees of coarseness and it is often used to clean the metal. Its effect is to produce a series of scratches or cuts in the metal. *Abrasives* of varying degrees of coarseness may be used, such as alundum, and carborundum (which are artificial abrasives). Emery, bath brick, pumice powder, tripoli, or rouge (the last two being used for finishing abrasives) may be used dry with a cloth, or mixed with a little machine oil. When used on cotton wheels, the abrasive is usually made into a cake by mixing with tallow, which helps to hold it on the wheel while in rotation. The metal scratch brush is often used to clean metals and polish them. It gives a distinct type of finish peculiar to itself.

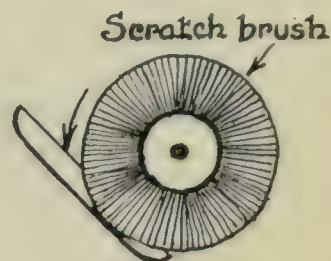
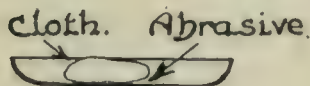
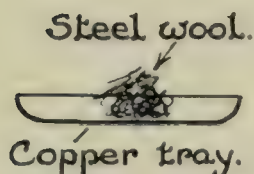
Cleaning the Copper. Pickling copper is a common method of cleaning it in a shop. The pickle may be a weak solution of one part acid and seven parts water, but it is much quicker to use a *Bright dip*, which consists of one part sulphuric acid, and one part nitric acid. The work should be suspended by copper or brass wire (do not use iron wire) for a few seconds only. Then it should be washed in clean water, and dried in saw-dust. When it is dry, it is ready for colouring.

Colouring Copper. There are many solutions for colouring copper, the commonest being a solution of potassium sulphide (liver of sulphur). If a piece of potassium sulphide, about a one-inch cube, is mixed with one pint of water, it will be about the required strength. The stronger the solution, the darker will be the colours obtained. Articles may be immersed in the solution or it may be applied with a cloth. *Note:* Chemical cleanliness is essential for the copper to be evenly coloured. If the copper is gently heated, the solution will dry quickly and then the high-lights may be relieved by rubbing with a rag and a little machine oil; or, if necessary, with a fine abrasive, such as tripoli or pumice powder.

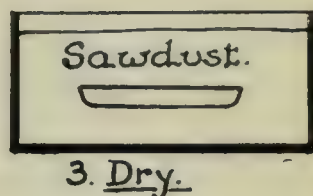
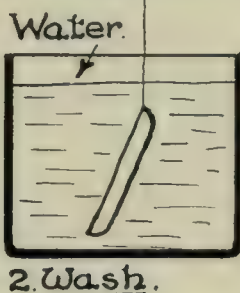
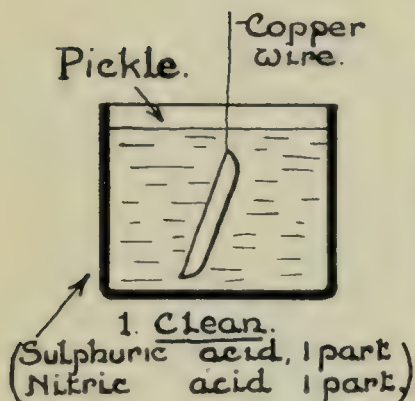
Finishing. It is necessary to protect the copper from the effects of air and moisture if the colours are to be preserved. Articles that are not to be handled may be lacquered by immersion or lacquer may be applied with a soft camel-hair brush. It is well to "stove" the object immediately in order to bake the lacquer to a temperature that your hand can comfortably stand. *Waxing:* Articles that are to be handled should be waxed. Warm the object gently, apply the wax, allow to cool, then rub lightly with a soft cloth until the surface is highly polished. Beeswax is commonly used for this purpose.

POLISHING, COLOURING, AND FINISHING COPPER (Continued)

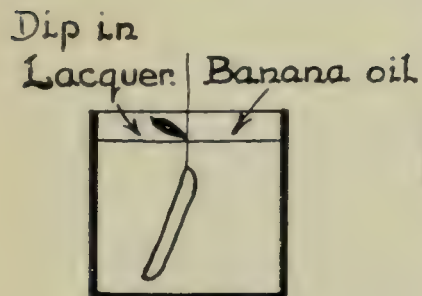
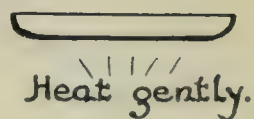
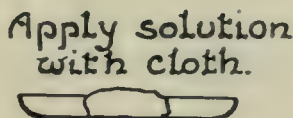
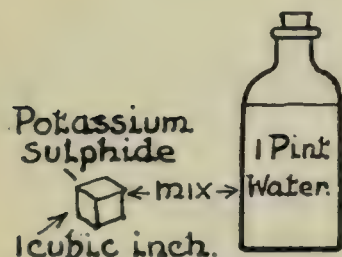
POLISHING.



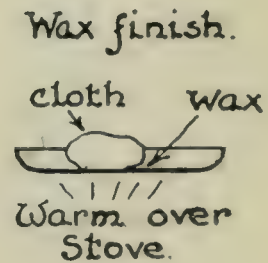
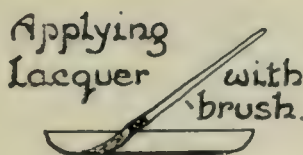
CLEANING.



COLORING.



FINISHING.



MAKING A SOLDERING IRON OR COPPER

The copper point or "bit" may be made of round or square copper stock. As rod copper is rather expensive material, it will be well for the pupil to study economy in handling it, and particularly in cutting off only sufficient material for actual requirements.

Hammering Point. It is more economical to hammer the point on the copper bit, because if it is sawn, the pieces cut off cannot be used for anything. If a bar of copper is used, the pupil will find it easy to control under the blows of the hammer, but if the stock is first cut off, it must be held in tongs, and some difficulty may be found in holding the copper steady.

The end of the metal should be held near the edge of the anvil or metal block, so that the hammer will not strike the surface of the anvil. The metal is drawn out or stretched to form the point and hardens under the hammer blows, so that it must be heated to make it soft.

Sawing the Point. The point may be sawn instead of hammered, as an alternative. Lines are "laid out" on the work with a scribe, marking the size; then the two opposite sides are sawn and lines are "laid out" on these sides, then sawn on opposite sides again. If the saw cut is vertical in the vise, the pupil will find it easy to cut accurately to the line, after which all sides may be filed smooth.

Drilling. It is essential that the hole drilled in the copper bit be in line with its axis, otherwise, when the iron stem is put in, it will not be in line with the bit. If a hand drill is used, there is great danger that the hole will be out of line (or alignment).

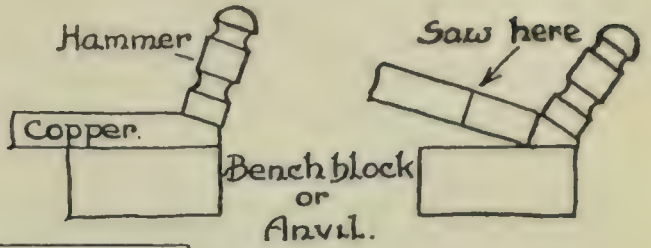
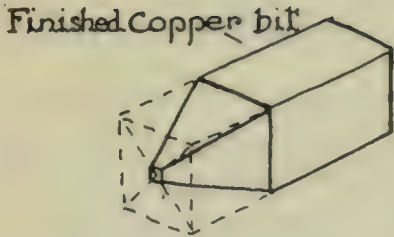
To drill in the lathe, the copper should first be centre-punched on both ends exactly in the centre of the stock so that the drill can start correctly true on one end, while the other end can be held on the dead centre. A "dog", or any other holding device, is necessary to prevent the copper from turning, and the copper must be held hard against the dead centre to prevent it slipping off the point.

To drill in the drill press, it is necessary to hold the copper bit in a vise or a "jig". Make quite sure it is held vertical. Any square corner may be used to check this. If any cutting lubricant is required, milk may be used.

Filing. The tang on the stem is filed with a safe-edged file, the stem parallel with the vise jaw and projecting from the vise the required length of the tang in order to form the necessary shoulder. A groove is filed around the stem so that the copper may be punched to fill the recess and lock the copper bit securely to the stem.

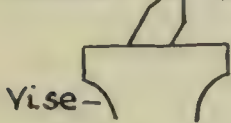
Cutting the tube for the ferrule is only necessary when a wood handle is made by the pupil in the workshop. The tube may be conveniently cut off on the lathe, or, if the tube is cut off with a saw when held in the vise, lead jaws must be used to prevent marking and squeezing the tube out of shape.

MAKING A SOLDERING IRON



HAMMERING

Hacksaw blade 1-24 teeth per inch.



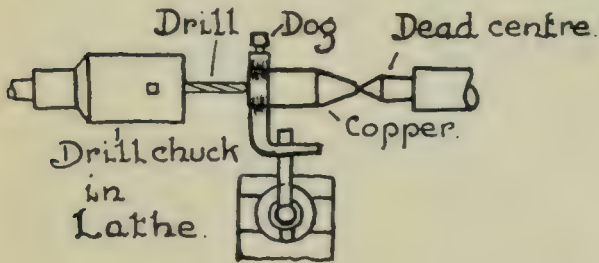
Second cut.



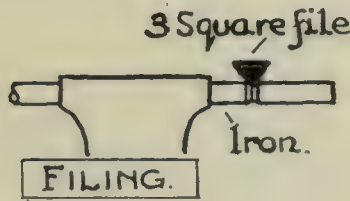
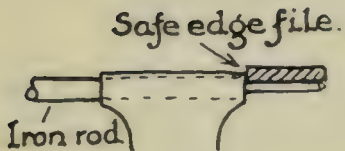
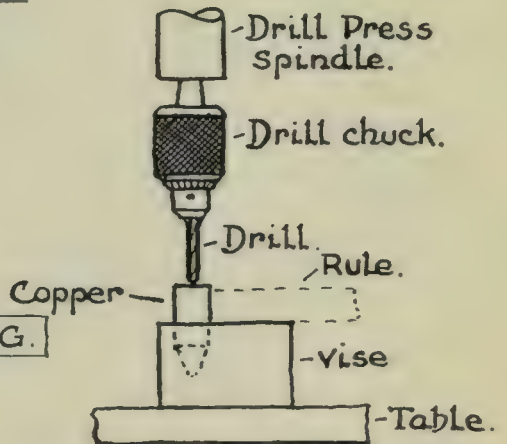
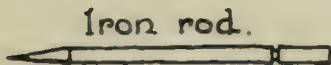
SAWING



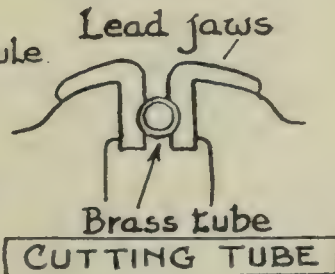
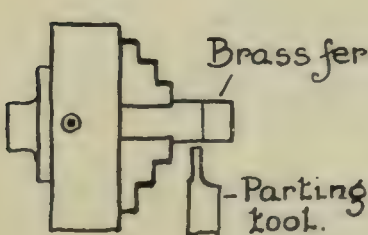
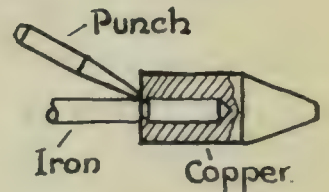
Last cut.



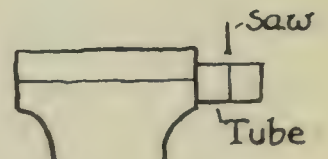
DRILLING.



FILING.



CUTTING TUBE



COPPER: PROPERTIES AND USES

The pupil will be given the opportunity of making some interesting and useful projects of copper, similar to those illustrated on the diagram sheet (page 57). This lesson plan will introduce the beginner to some of the things which will help him to work in copper intelligently and assist him to solve some of the difficulties he will probably encounter.

Forms of Copper. Soft or annealed copper may be obtained by heating the metal to a pink colour, then plunging it into water. *Hard copper* may be obtained by hammering, spinning, drawing, or rolling. *Tinned copper* can be purchased, or it can be tinned by the pupil. *Planished copper* can be purchased, or the metal can be planished by a special hammer with its face polished to looking-glass brightness, the metal being held on a very smooth block of metal. *Oxidised copper* can be obtained by the use of chemicals or by heating.

Uses of Copper. Owing to the fact that copper practically does not rust, and is a good conductor of heat and electricity, it has many uses. It can be purchased in sheet, bar, rod, and tube form. Copper nails are used in boat building because they rust very little. A substance called "verdigris" forms on the nails when exposed to water. Rivets are made of copper because the metal is soft, easily riveted, and does not rust. Burrs are used when riveting to wood; the burr prevents the rivet from pulling through the wood.

Fluxes. *Sal ammoniac* is used in tinning a soldering iron or in soldering. It is a white crystal made by neutralizing hydrochloric acid with ammonia. The mixture, when gently heated, forms crystals radially. *Fluxite* is a soldering paste in common use. *Resin* is a good flux, on account of its non-poisonous quality. *Killed spirits* are made from hydrochloric acid and zinc, diluted with an equal quantity of water. *Borax* is the flux used for hard soldering copper.

Copper Sulphate, or Bluestone, can be made into a solution with water and a little sulphuric acid. This solution is employed to copper the surface of iron and steel.

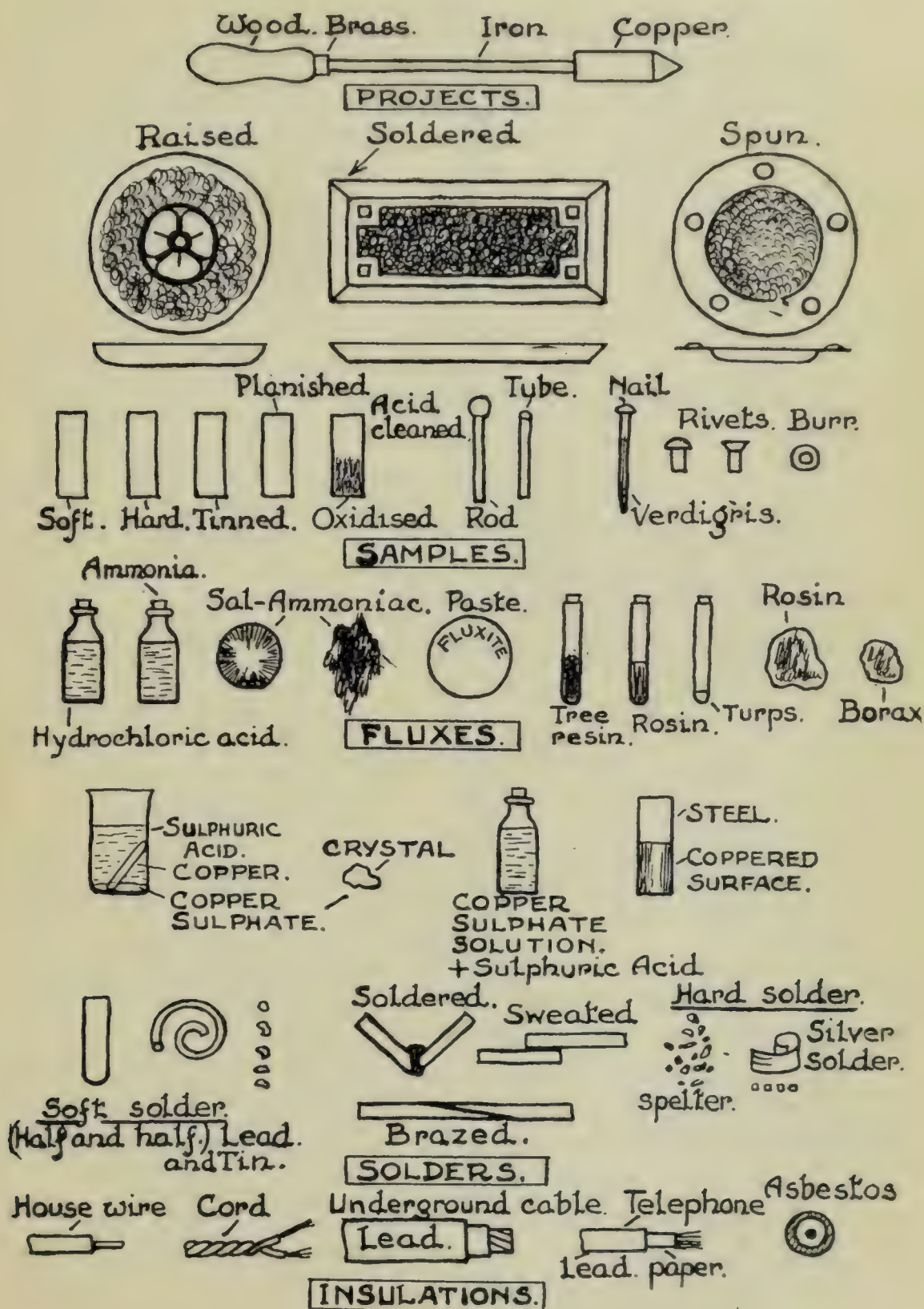
Soft Solder is made of half lead and half tin. It can be purchased in bar or wire form. A soft-soldered joint is comparatively a weak joint with the solder exposed. A sweated joint is stronger and the solder is not exposed.

Hard Solder is used when a strong joint is required. Spelter and silver solder are the two forms used. Intense heat and a clean charcoal fire or a torch are required to make a satisfactory joint. This operation is commonly known as *Brazing*.

Insulations for Copper are used when it is carrying electrical current. Various substances are used, such as rubber, gutta percha, paper, asbestos. Underground and underwater cables are protected by an outer coating of lead.

Non-ferrous metals. Non-ferrous metals are metals that do not contain iron or ferrite, such as, copper, brass, zinc, tin, lead.

COPPER: PROPERTIES AND USES (Continued)



OBJECTIVE TEST: COPPER

1. Copper is a (hard) or (soft) metal?
2. Copper hardens when.....
3. Hard copper is softened or annealed by.....
4. Copper is a (good) or (bad) conductor of heat?
5. Copper is a (good) or (bad) conductor of electricity?
6. Copper is.....when used for food utensils.
7. Tea sets are often made of copper, then.....plated.
8. The scale which forms on heated copper is called.....
9. Copper is plated when used for food utensils, because a green substance, called.....is a deadly poison.
10. Rivets used in building small boats are made of....., because.....
11. The fluxes used in soft soldering copper are :
 - (1)
 - (2)
 - (3)
12. The flux used for hard soldering is.....
13. Iron and steel can be copper-coated by dipping in.....
14. Soft solder for copper is made up of.....and.....
15. The hard solders for copper are.....and.....
16. Some insulations for copper when carrying electrical current are :
 - (1)
 - (2)
 - (3)
17. How can you make a copper-sulphate solution for copper-coating iron or steel?
18. What "resist" is used to protect copper in etching?
19. What does an etching-solution for copper consist of?
20. How do you make a colouring solution for copper?
21. What is the name of the black scale that forms on heated copper? How can this scale be removed when quenching the heated copper?
22. Should copper be hammered hot or cold, in forging a soldering copper? State reasons for your answer.
23. Sketch four stages in the making of a round copper tray.
24. Sketch, in section, a copper plate, showing two methods of etching the letter "O".
25. State four methods of polishing a copper project.
26. How can copper be preserved from oxidation?

COPPER PROJECTS



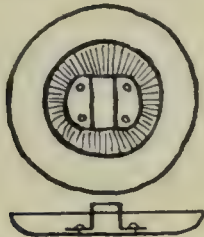
Trinket Tray.



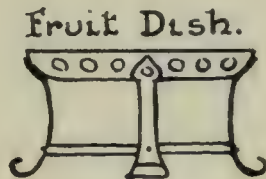
Lamp.



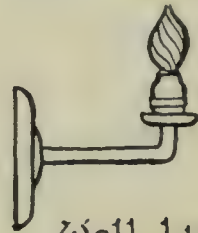
Door Knocker.



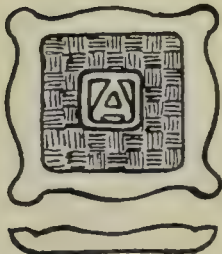
Match Tray.



Fruit Dish.



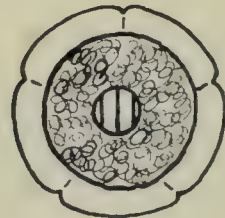
Wall Light.



Card Tray.



Lamp.



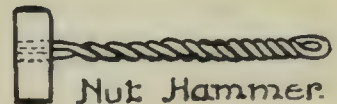
Nut Cracker



Tray Handle.



Eseutcheon.



Nut Hammer.

FILING AND POLISHING WORK IN A LATHE

The simplest operation that can be carried out on a small lathe is to file and polish work. The pupil has already used a power machine in the form of a drill press, and now he is introduced very simply to a lathe. The axis of the drill is vertical while the axis of the lathe is horizontal, and it is possible to vary the speed of its spindle according to the work being done.

It is very necessary to oil the lathe first with good machine-oil to prevent friction and overheating of the bearings. The work is held in the universal chuck, as in diagram (2). The chuck holds the work true and turns it around as the spindle of the lathe rotates.

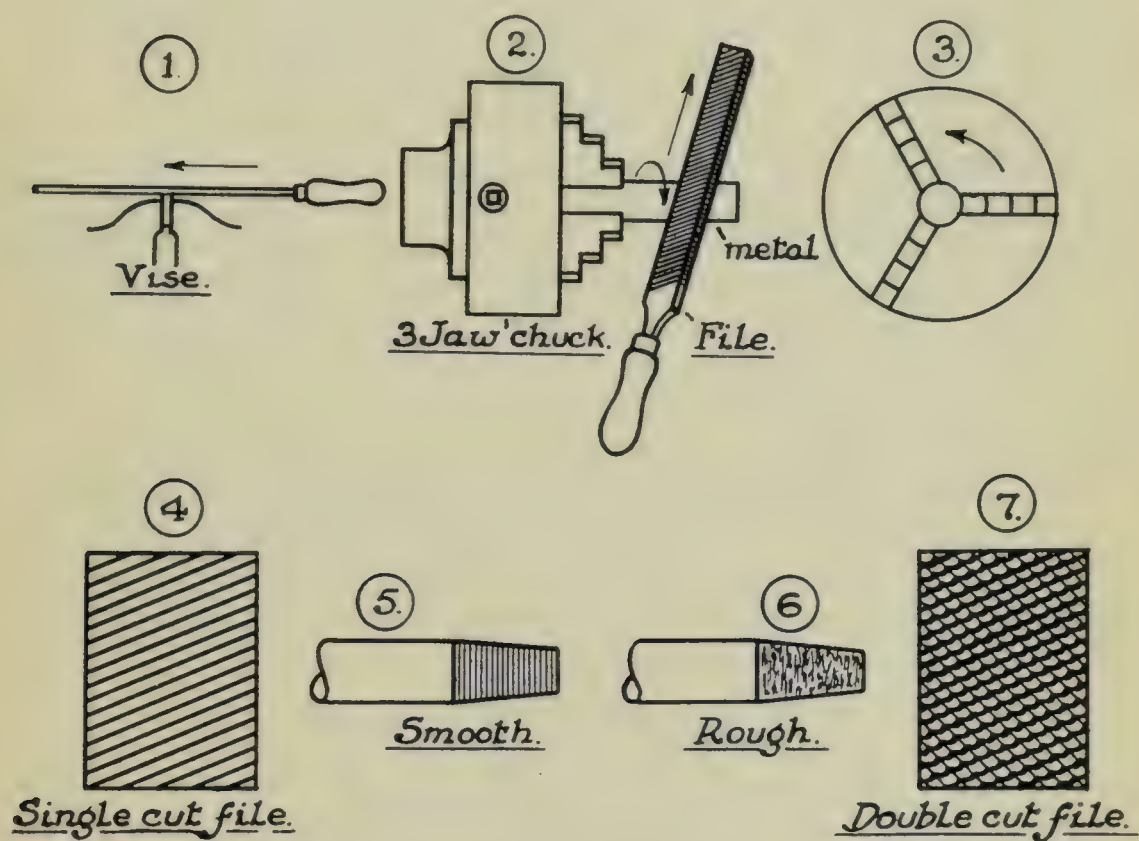
Filing work in the lathe. Work is filed in the lathe to make a round smooth surface on it, but it is never as truly concentric as work which is "trued" by cutting tools in the lathe. If one compares filing in a vise to filing in a lathe, one can see how quickly the lathe does its work as compared with a hand-filing operation, as in diagram (1), and pages 98, 99, 100.

The double cut file (diagram 7). This file is selected for rough filing because it is quick-cutting. It has two rows of teeth cut in opposite directions, which produce a surface on the metal that is slightly rough (diagram 6).

The single-cut file (diagram 4). The single-cut file has a single row of teeth and is used after rough filing with the double-cut file to remove the marks on the metal made by that file. A fine tooth single-cut file produces an even smooth finish on the work, as shown in diagram (5).

Direction of filing in the lathe. Diagram (2) shows a sketch of a lathe chuck and work being filed. It is necessary that the operator realizes what would happen if the file were not used correctly. If the file were turned towards the jaws, there would be great danger that it would be caught by the jaws and hurt the operator. Be sure to use the file as in diagram (2), pointing away from the chuck. Take long steady strokes, using as many teeth as possible, and therefore getting a maximum cutting action.

FILING AND POLISHING WORK IN A LATHE (Continued)



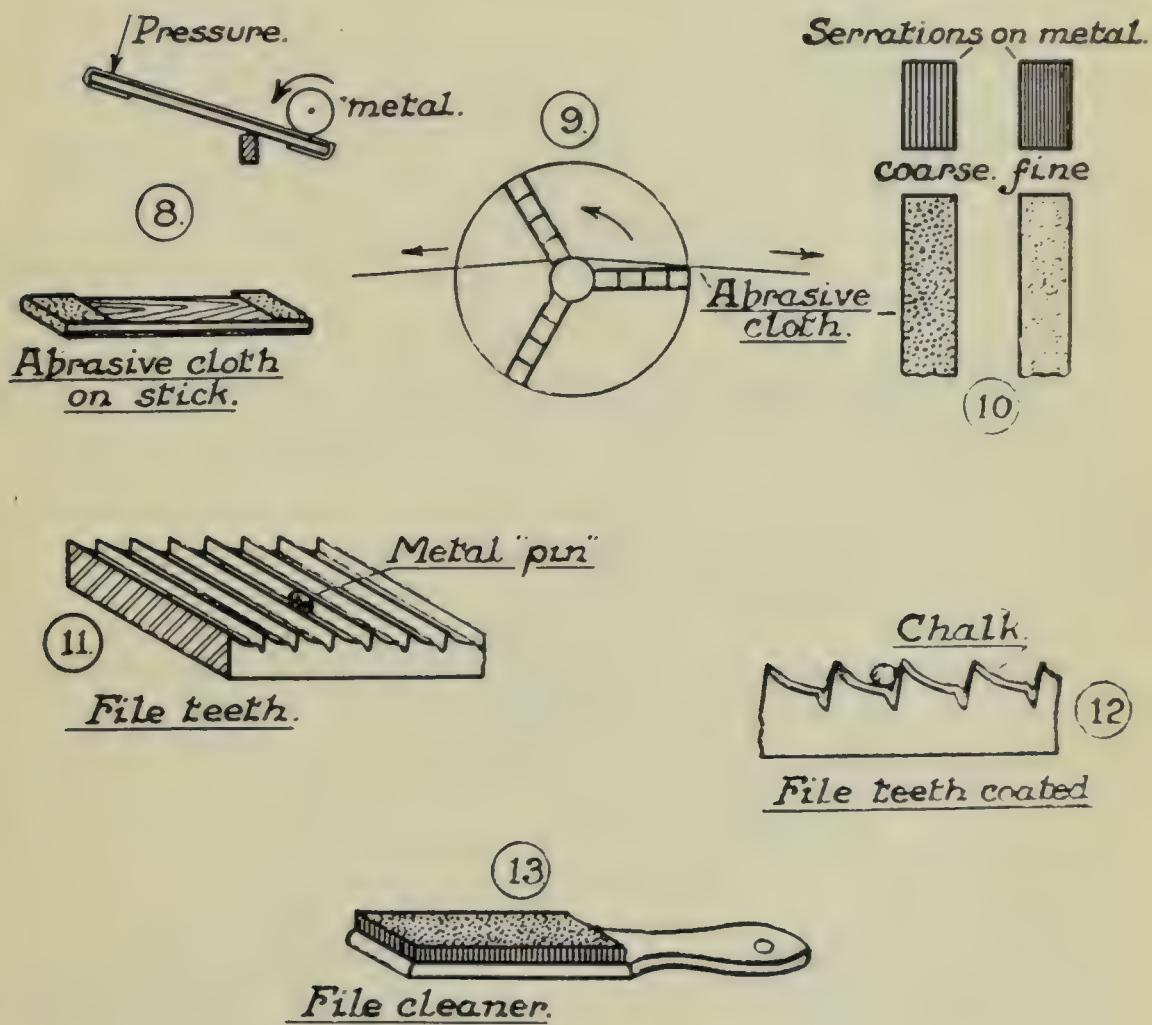
FILING AND POLISHING WORK IN A LATHE (*Continued*)

Keeping the file clean. Diagram (11) shows what occurs in filing. Little pieces of metal become lodged between the teeth of the file; and if they are not removed, the continual rubbing under pressure hardens the "pins", as they are called. Then, being harder than the metal from which they were cut, they proceed to scratch the surface. To prevent this action of "pinning" from spoiling your work, clean the file with a file card (diagram 13), or, before you start to file, coat the file with ordinary chalk, which prevents the pins to some extent from sticking to the teeth, as shown in diagram (12).

Polishing work with abrasive cloth. The surface of work, if examined under a magnifying glass, will be found to be "serrated", that is, little grooves are cut into it with the file teeth. These serrations can be reduced in size by the use of abrasive cloth (diagram 10). An abrasive can be obtained of varying grain size, from coarse to fine. A 120 grain size abrasive means that 120 grains, laid side by side, would measure 1". These abrasive grains are glued to cloth; so it is called abrasive cloth.

The common abrasives used for this purpose are emery (a natural abrasive), crystalline aluminum oxide (an artificial abrasive), or silicon carbide (an artificial abrasive). They are sold under varying trade names, such as, aloxite or carborundum, alundum or crystolon. A strip of abrasive cloth, about 1½ inches wide and 10 inches long, is used, stretched across the rotating metal, as shown in diagram (9). Greater pressure can be obtained by using the stick shown in diagram (8). If a finer polish is required, use a finer grain size, and finish ferrous metals (metals containing iron) with the cloth coated with machine oil. When the oil is wiped off the work, it has a bright finish. Do not hurry from one stage to another in polishing until every part of the surface of the metal has serrations of equal depth. That is, all deep scratches must be removed with the file before the abrasive cloth is used.

FILING AND POLISHING WORK IN A LATHE (Continued)



SIMPLE HARDENING

Before beginning to make any article which has to be hardened and tempered, it is necessary that the beginner should be absolutely certain that he obtains tool steel.

Spark test for carbon tool steel. This is a very simple and reliable test for carbon tool steel, as shown in diagram (1). The sparks given off are very profuse and starlike in formation. The starlike spark is always present when there is a good deal of carbon in the steel.

Heating steel preparatory to hardening. A small scriber point is illustrated in the lesson because it demands proper heating to prevent being spoilt. Heat the larger mass first, and allow the heat to move towards the smaller mass by conduction until all is uniformly heated (diagram 2). If the small point is heated, as in diagram (3), the small mass of metal shows a bright red heat before the larger mass shows any heat colour.

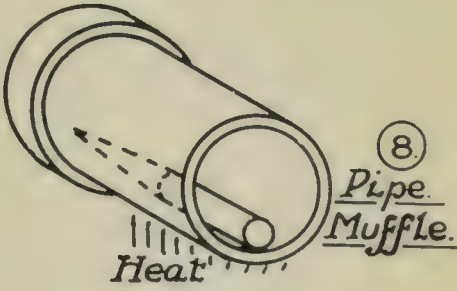
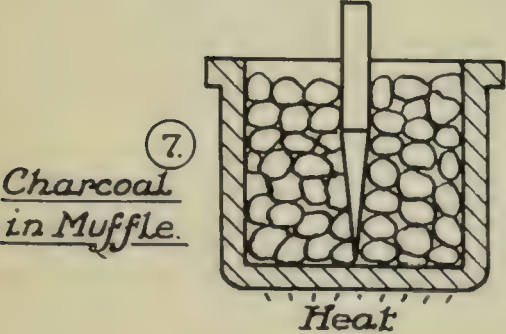
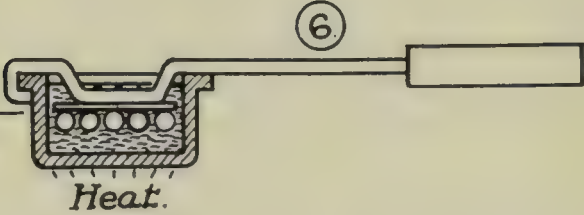
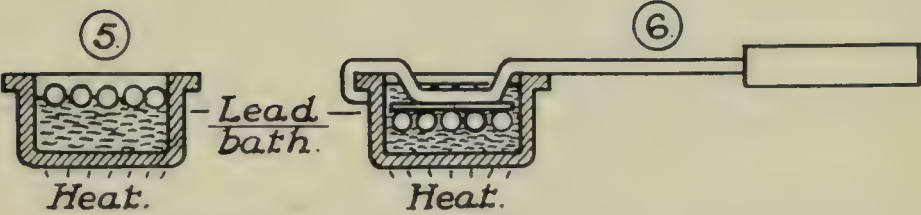
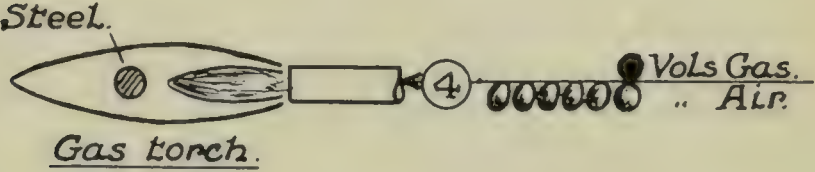
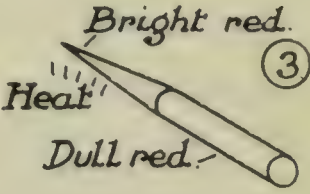
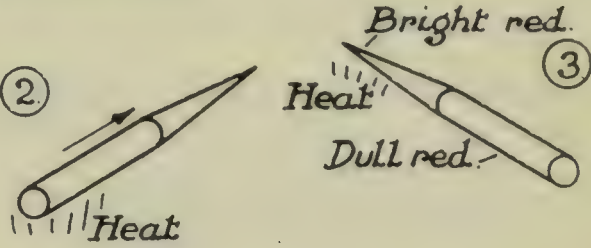
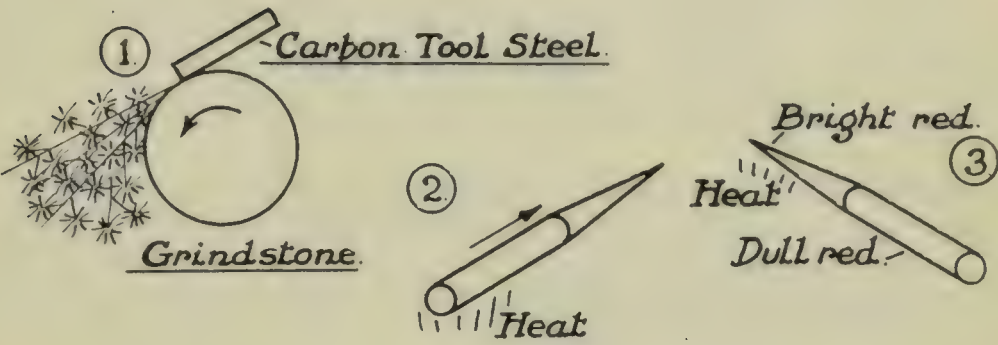
Use of a gas torch for heating. Diagram (4) illustrates a gas torch, showing that six volumes of air are required to mix with one volume of gas to give the correct mixture for a hot flame. The position in the flame is also important. Diagram (4) shows the position of the steel being heated just beyond the blue cone, where the air and gas have been properly mixed for correct combustion.

Methods of heating steel to prevent oxidation and decarburization. A lead bath is shown in diagrams (5) and (6). You will note that steel is lighter than lead, therefore it floats on the surface of the molten metal. The steel is kept beneath the surface by the folder, shown in diagram (6). This method provides a uniform heat and keeps the steel away from the air and the direct action of a fire or flame.

A charcoal muffle. A charcoal muffle, shown in diagram (7), affords a good method of heating steel because it not only protects the steel but it also gives additional carbon, as charcoal is rich in carbon.

Heating in a pipe muffle (diagram 8). This also affords a quick method, as it protects the steel from the direct action of the flame, but does not prevent oxidation.

SIMPLE HARDENING (Continued)



SIMPLE HARDENING (*Continued*)

A frequent cause of failure is that shown in diagram (9). The steel may be heated correctly but too much time may be taken before it is quenched. If so, the point cools off, so that the thick part may be hard and the thin point soft.

Hardening heat of steel. To harden a piece of carbon tool steel, the operator should heat the steel uniformly until it becomes non-magnetic. This can be tested with a magnet, as shown in diagram (10). The lowest heat is best, for if the steel is overheated, it becomes coarse in structure and very weak.

Quenching. Maximum hardness can only be obtained by taking out the heat from the steel as quickly as possible. Usually this is done by quenching in water, which makes the steel hard but very brittle. Then it is tempered to remove brittleness, strains, and occasionally some of the hardness also.

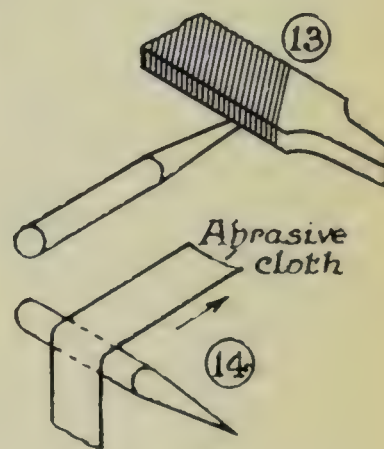
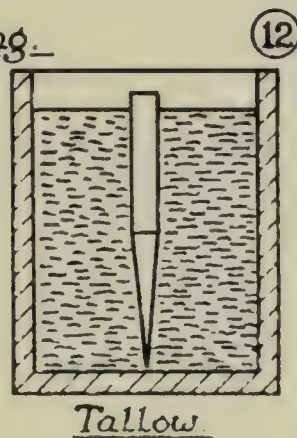
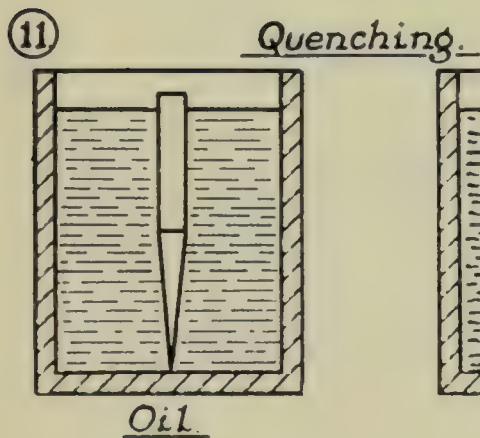
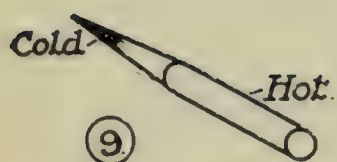
The simple hardening in this lesson requires no tempering, because the steel is quenched in oil or tallow, which cools it at a slower rate than water. It makes the steel file hard and partly tough and quite suitable for a scriber point.

Testing the steel after hardening. It is necessary that the operator should be certain that the steel is hardened properly. This is usually ascertained by testing it with the heel of a file (diagram 13).

The file must not cut the steel; that is, the steel must be harder than the file, or "file hard".

Polishing hardened work. Hardened work cannot be cut with tools, like annealed steel. An abrasive is the only thing that will cut the steel, so that it must be ground if it has to be cut to shape, or polished with abrasive cloth, as shown in diagram (14).

SIMPLE HARDENING (Continued)



TINNING AND SOFT SOLDERING

The soldering iron or copper (diagram 1) consists of three main parts: the copper bit, the iron stem, and the wooden handle. Copper is a good conductor of heat, that is, it takes in heat quickly and gives it out quickly when put in contact with another metal. Do not heat just the point of the copper, because it has a small mass and will be overheated before the remainder of the metal. Heat the thick part of the copper bit and it will conduct heat to the point and keep the point heated for a longer period than if the point only were heated. Wood, being a poor conductor of heat, allows one to use the soldering copper without discomfort to the hand.

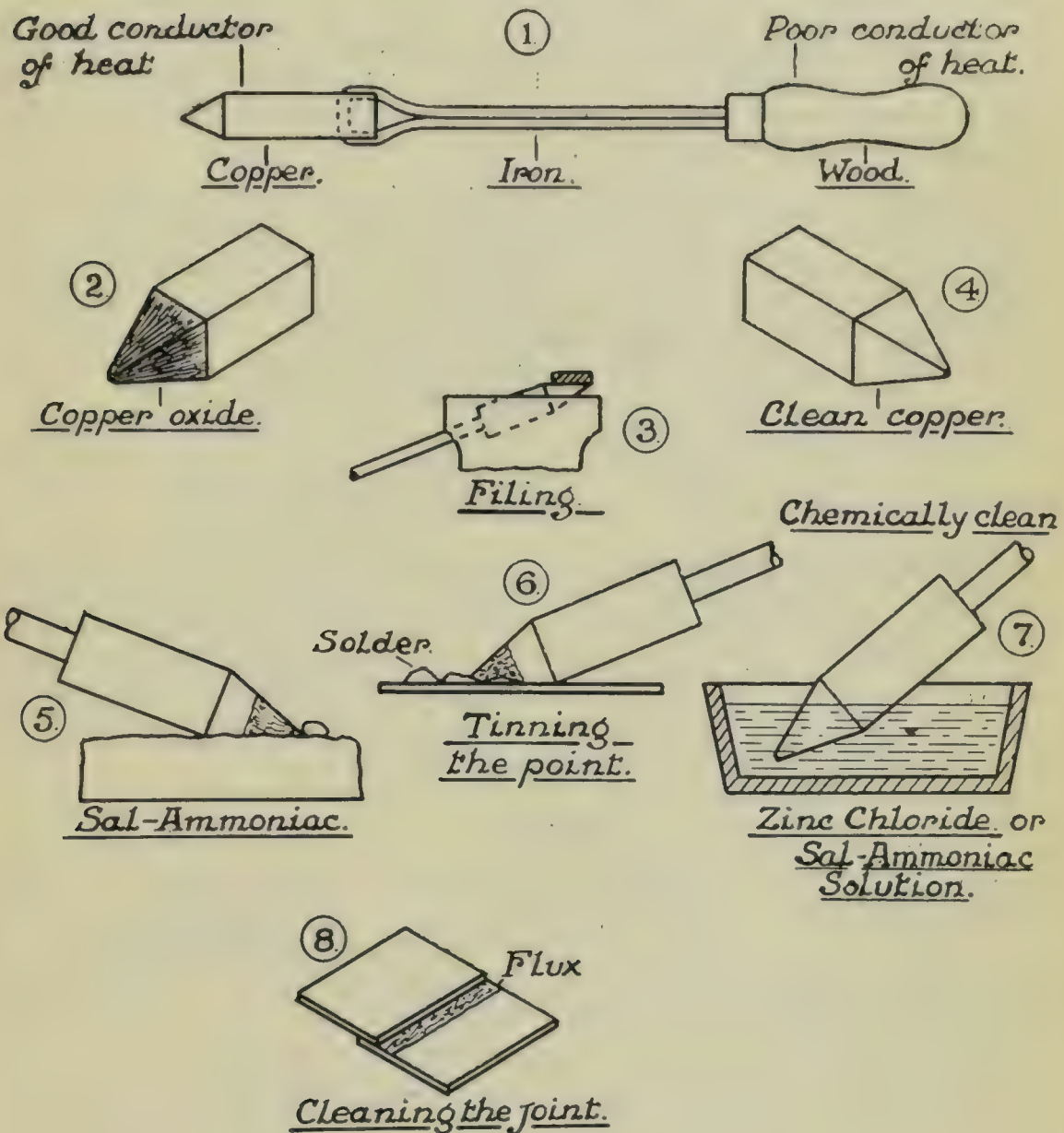
Copper oxide (diagram 2) forms on copper when heated in air, and the black scale so formed is a very poor conductor of heat. It is impossible to tin the copper until the black scale is removed. This is usually done by filing, as shown in diagram (3), with the copper held securely in the vise. Diagram (4) shows the copper after filing “physically clean”, but not “chemically clean”.

Tinning the point. *Method 1:* To tin the point, the first essential is that the copper be made chemically clean. One method is shown in diagram (5). A piece of soft solder is placed on a block of sal ammoniac, and the heated copper is rubbed on this block in contact with the soft solder. As soon as the point becomes chemically clean, the solder adheres to the copper and flows freely over the surface of the point.

Method 2 (diagrams 6 and 7): The hot copper is first dipped in zinc chloride or sal ammoniac solution, which “chemically cleans” the metal. Then rub it on a piece of tin plate, containing small pieces of soft solder. This readily tins the point.

Soldering a joint. The metal to be soft soldered, as shown in diagram (8), is first made chemically clean by the application of “flux”. The function of a flux is twofold. It cleans the joint, and causes the molten solder to flow all over the joint.

TINNING AND SOFT SOLDERING (Continued)



TINNING AND SOFT SOLDERING (*Continued*)

Applying the soldering copper to the joint is illustrated in a plan and elevation in diagrams (9) and (10). Let the soldering copper make as much contact with the metal as possible, to conduct as much heat into the metal as it can in the shortest time. When the metal to be soldered is as warm as the copper bit, it is moved slowly along the joint. If the joint is just as hot as the soldering copper, the solder will cool slowly and leave a smooth joint, well soldered, as in diagram (11).

Soldering temperature. Soft soldering is a low-temperature operation as compared to hard soldering or brazing, which is a high-temperature process. Soft solder usually consists of half lead and half tin, and melts at 370 degrees F.

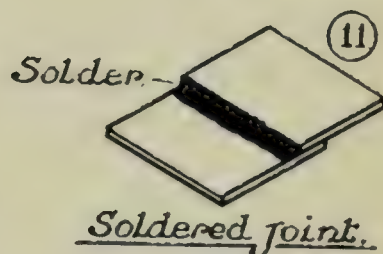
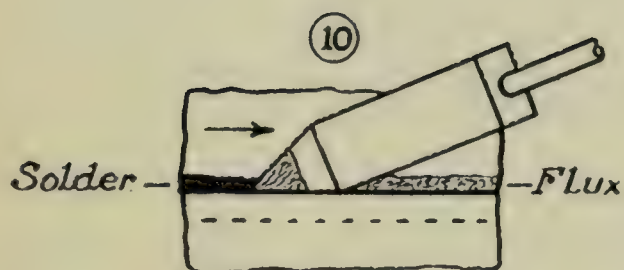
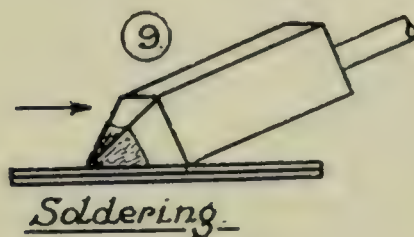
Fluxes: A solution of *killed spirits* is prepared by dissolving granulated zinc in hydrochloric acid (sometimes called muriatic acid or spirits of salts). A gas, hydrogen, is given off. When all the gas is given off and there is still zinc present, the acid is said to be "killed". Sometimes a piece of washing soda or sal ammoniac is added, to make sure that any acid which may be present is neutralized. To this solution add an equal part of water, making it ready for use.

Paste flux is not so liable to cause rust as killed spirits. It is made by boiling zinc chloride until only crystals remain. These crystals are then ground into a fine powder and mixed with vaseline.

Sweating. A sweated joint is a strong clean joint. Two pieces of metal (see "A", diagram 12 and "B", diagram 13) are first coated with solder. Then they are placed together, as in diagram (14). Heat can be applied by the soldering copper, or by means of a torch, until the solder melts, when the parts are joined together. If pressure is applied when the joint cools, a closer joint will be obtained and very little solder can be seen at the edge of the joint.

Fluxes	Metals	Remarks
Killed spirits.	Tin plate, brass, copper, iron and steel.	Remove oxide. Wipe off flux after use, or it will cause rust.
Hydrochloric acid with 90% water.	Galvanized iron, zinc.	
Sal ammoniac.	Tinning copper, iron and steel.	Good for tinning copper.
Tallow.	Lead, pewter, white metals.	For metals of low melting points.
Rosin.	All metals that are scraped or filed bright.	Does not remove oxides. Used in electrical work. Does not cause corrosion after use.

TINNING AND SOFT SOLDERING (Continued)



HARDENING AND TEMPERING

The effect of hardening and tempering carbon tool steel. Diagram (1) shows a group of samples. The first sample on the left is a piece of steel cut off an annealed tool steel bar. When tested for hardness on a scleroscope (a hardness-testing instrument), it measures 25 on the hardness scale of the instrument. This sample is soft.

The second sample has been hardened to maximum hardness. This sample measures 94 on the scale. Hardened work that has been quenched in water is brittle and full of hardening strains.

Tempering is a reheating process, following hardening, to remove brittleness, to take out strains, and in some cases to take out some of the hardness of the steel, in order to make it the proper degree of hardness for the work it has to do. When the third sample is heated to 428 degrees F., the hardness has dropped from 94 to 83, and as the tempering temperature increases, so the hardness decreases, as shown by the remaining samples.

Forging tool steel (diagram 2). Care must be exercised in heating tool steel. For forging, it must be heated slightly higher than its hardening heat, to make it plastic and easy to shape with the hammer. If the steel is hammered when below a cherry red colour, it is likely to cause cracks by straining it. Hammering steel at the proper heat improves it, and gives it a fine grain structure.

Normalizing (diagram 3). Normalizing is a process of heating the steel beyond its hardening heat and allowing it to cool off to a black heat. This removes strains put in the steel by forging, and makes the steel uniform before the hardening operation is started.

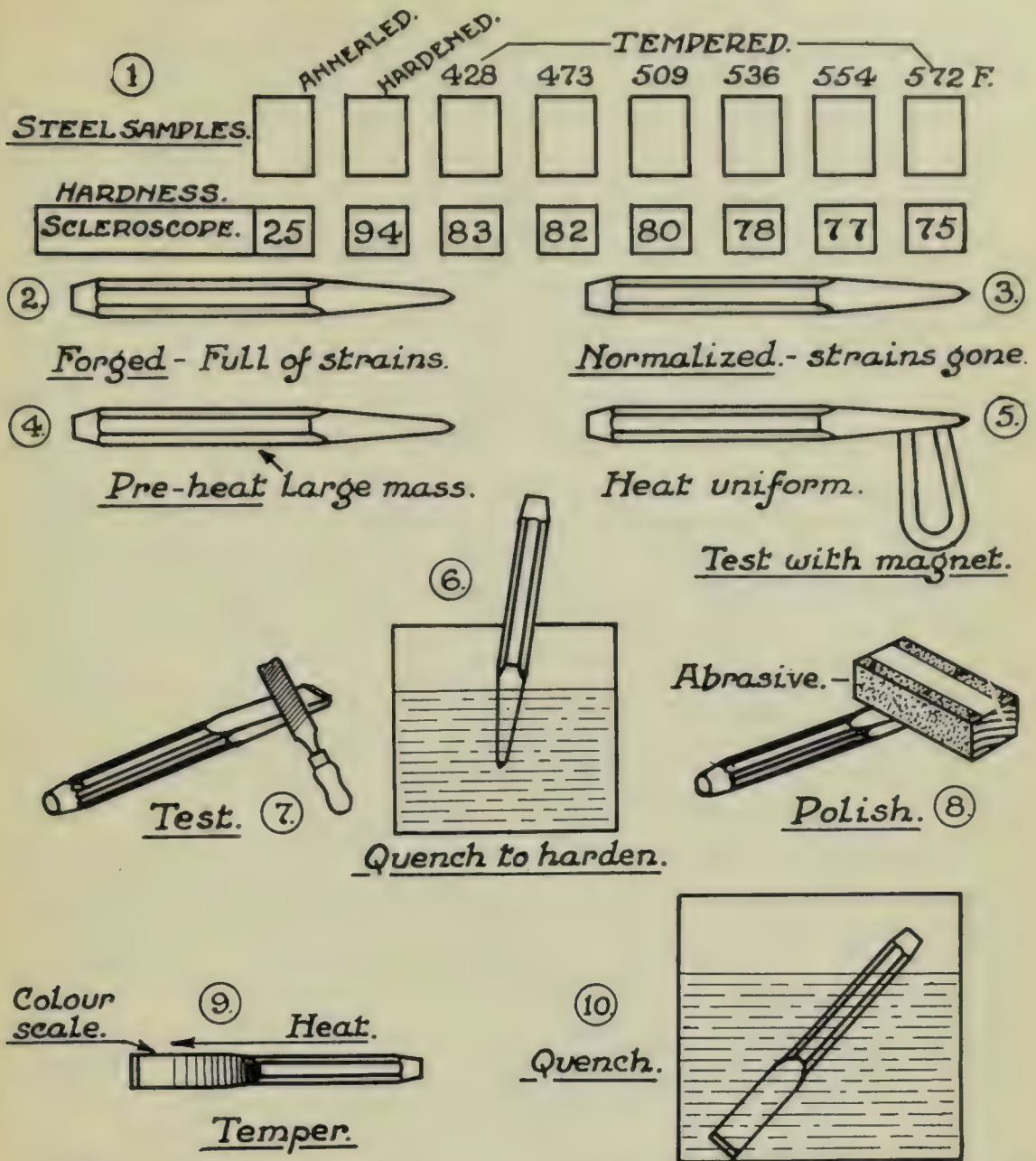
Pre-heating tool steel before hardening. Pre-heat the steel slowly and uniformly. If it has an irregular mass, as shown in diagram (4), heat the larger mass first, and allow the heat to move to the smaller mass by conduction.

Testing steel for correct hardening heat. When the steel has a uniform heat colour, test it with a magnet, because carbon tool steel becomes non-magnetic when it reaches its correct hardening heat (diagram 5). If the steel is heated beyond this point, it has a very coarse weak structure when quenched.

Quenching (diagram 6). To obtain maximum hardness, quench quickly in water and keep the steel moving. Quench only the part to be hardened and do not quench it outright. As soon as you can hold the steel under water with your fingers, remove it while it is warm, as it is likely to crack if quenched outright.

Test for hardness. Use the heel of a file to test for "file hardness" immediately after quenching. If the file will not cut the steel, it is properly hardened.

HARDENING AND TEMPERING (*Continued*)



Tempering. Temper steel immediately after hardening. Polish the surface of the hardened part with an abrasive cloth, as shown in diagram (8), to remove the oxide film. As the heat moves down from the part that remains hot towards the point, a colour scale shows on the bright surface of the metal. First, a light straw colour appears, followed by dark straw, purple, and blue (diagram 9). As soon as a purple colour reaches the point, the temper is suitable for a chisel, and the heat is stopped by quenching (diagram 10).

Testing the hardened tool. The tool should be tested, after being tempered, by being used to carry out the work it is intended to do. If a chisel, test by cutting a piece of wrought iron held in the vise, or by cutting the hard skin of cast iron.

STEEL: PROPERTIES AND USES

The pupil will learn that steel is not a very easy metal to work with, chiefly on account of its strength and spring. Articles made from steel, however, have a greater value to the user because of the varying degree of hardness it is possible to obtain with it, and because of the work it can do when it is made into tools. The pupil will discover some of the peculiar properties of steel, by cutting it to length, filing, bending, forging, and hardening and tempering it.

Burnt steel. If steel is heated to an extreme, it will be ruined. Iron can stand a white heat, but steel will not. The carbon content of steel varies the hardening heat. Low-carbon steels have a higher hardening heat than high-carbon steels; and high-carbon steels require very careful handling, particularly when heated.

Hardening cracks are the common result of careless treatment. They often show themselves after hardening and are caused either by shocks (as in hammering at too low a heat), or by overheating and sudden quenching. Before hardening the pupil would be well advised to normalize or anneal the steel. This gives all the internal strains an opportunity to be equalized throughout the steel.

Hardening heats and temper colours. Judging heat or temper by colour varies much with individuals. Experience alone will give proper judgment; but if colour scales for hardening heats and temper heats are available, they will help as a guide.

Blued steel. Steel can be blued for laying out purposes by heat alone; but a more permanent blue may be obtained by heating ten parts of nitre to one part of black oxide of manganese, and immersing the work in it. This improves the appearance of the metal and to some extent prevents rust.

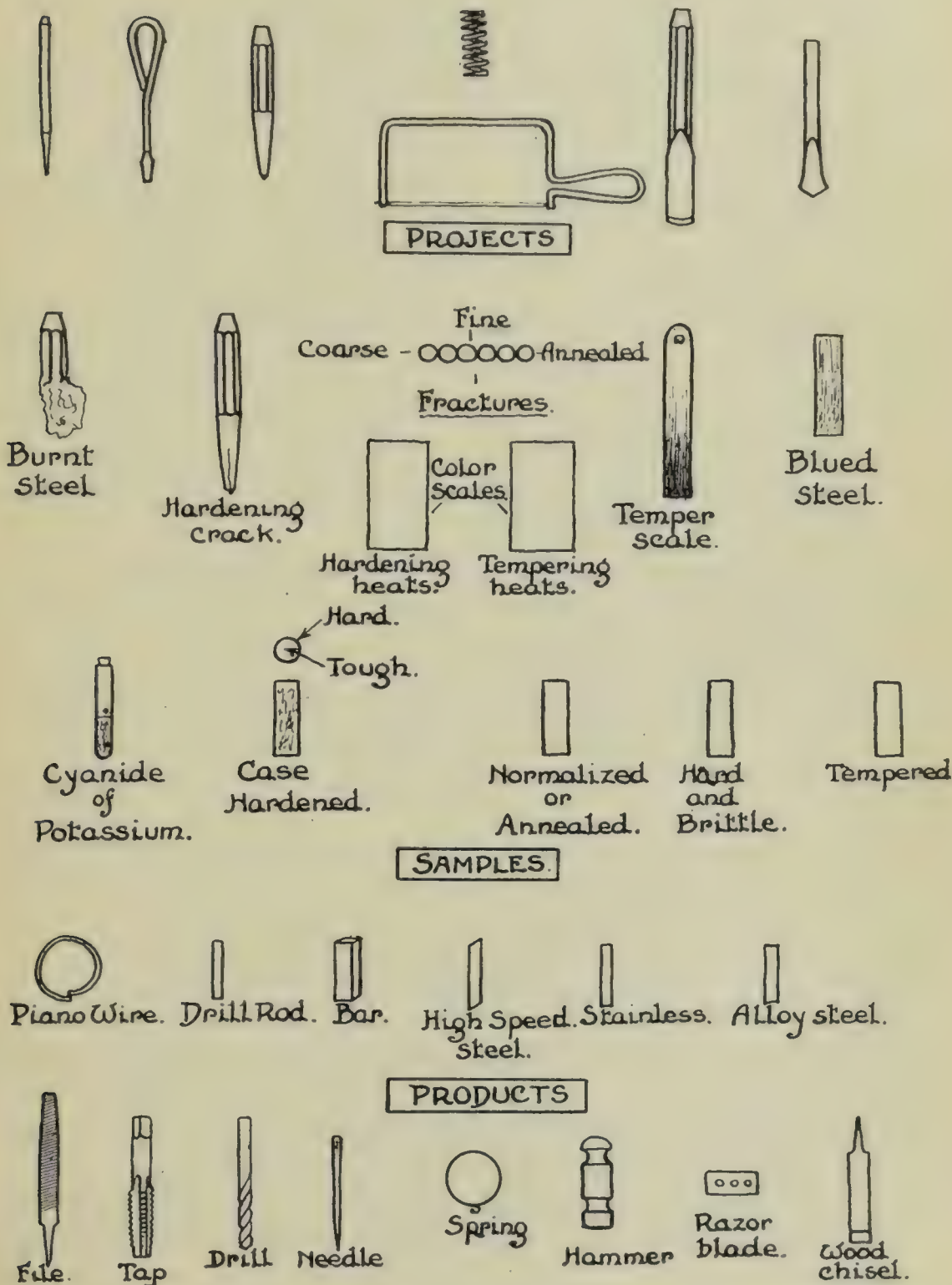
Case-hardening. Iron and low-carbon steels cannot be hardened, but the outer part of the metal can be made into a steel by allowing it to absorb carbon, such as is provided by cyanide of potassium and other carbonaceous materials. The depth, of course, depends upon the time it soaks in the heated cyanide. If quenched from a red heat, the outside will be glossy hard and the inside tough. A beautiful mottled effect also results from this operation.

Normalizing, or annealing, is a method of heating the steel beyond its hardening heat and allowing it to cool very slowly. This removes all strains before hardening and refines the grain of the steel.

Hardening steel. If steel is heated until it is non-magnetic and then plunged into water from this hardening heat, it becomes glassy hard and brittle and cannot be filed. In this state, it is of very little practical use.

Tempered steel. Steel is tempered to remove brittleness and to make it of the required degree of hardness for the work it has to do.

STEEL: PROPERTIES AND USES (Continued)



OBJECTIVE TEST: STEEL

1. One of the chief features of carbon tool steel is that it can be and.....
2. If steel is abused by intense strains, it will show it by.....when hardening.
3. Steel is an (easy) or a (hard) metal to bend.
4. The hardening heat of steel can be tested by use of a.....
5. Steel hardens when heated and quenched in.....
6. Hardened steel is also.....
7. Tempering is a process of reheating steel after hardening to remove.....and some of its hardness.
8. Hard steel can be.....to make it soft.
9. Iron and low-carbon steel can be given a hard exterior by a process called.....
10. This process can be carried out by use of a substance rich in carbon steel, called....., which is a deadly poison.
11. Low-carbon tool steel requires a (higher) or a (lower) hardening heat than high-carbon tool steel.
12. Razor blades have (more) or (less) hardness than springs.
13. The tang of a file is (soft) or (hard), and the blade is.....
14. Steel is usually cut off to length in small quantities by.....
15. Steel is easily overheated and of little use when.....
16. Explain what is meant by a 90 point carbon steel.
17. Place the following in the order of their carbon content, highest first, lowest last:
(a) A file, (b) A piece of band iron, (c) Cold-rolled shafting, (d) A centre punch.
18. Name four metals which are used for cutting tools.
19. State two methods of giving steel a blued surface.
20. Define, "hardening", "tempering", "normalizing", "annealing".
21. Which quenching bath would make steel the hardest? (state reasons): (a) Water, (b) Oil, (c) Tallow.
22. How would you heat steel for hardening to prevent the following: (a) Oxidation, (b) Decarburization, (c) Cracks.
23. How would you explain the following: A pointed tool when quenched outright had a soft point, but was hard in the thicker portion?
24. State three methods of cutting off tool steel. What laying out tools are made of tool steel?

TOOL STEEL PROJECTS



Screwdriver.



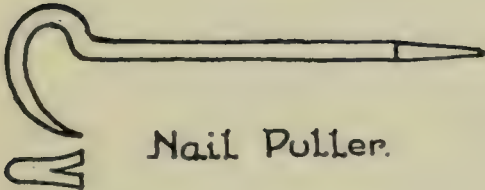
Screwdriver.



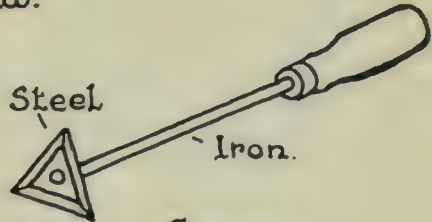
Awl.



Coping Saw.



Nail Puller.



Scraper.



Cold Chisel.



Drill.



Punch.

THE BENCH LATHE

The Bench Lathe, illustrated in diagram (1), is quite suitable for a beginner in lathe-work. All complex parts have been eliminated and it is safe to operate. Elementary fundamental operations can be carried out on this 9" lathe at a comparatively small cost.

The Lathe Bed is made of cast iron. Its upper surface is accurately machined with "ways", or tracks, on which the carriage carrying the tool moves in a path always parallel to the axis of the lathe centres.

The Tailstock can also be moved on the "ways" and can be bolted to the bed in any desired position.

The Headstock is fastened permanently to the bed, and is made strong to resist the pressure from the cutting action of the tool, which is usually fed in the direction of the headstock.

The Carriage represents the whole of the moving unit along the top of the bed. *The Saddle* rests across the ways and supports the *Cross Slide* used for squaring work. The cross slide supports the *Compound Slide Rest*, which can be set at any angular position in respect to the lathe alignment.

The Apron carries the mechanism which connects the handwheel to the rack, to give long feed to the tool.

Variation of spindle speed. (1) *The speed cone* is a device for varying the lathe speed. A similar cone is placed in the reverse position on the driving shaft, called the "countershaft".

(2) *The back gears* (diagram 5) provide a further range of reduced speeds, in addition to the varying speeds provided by the speed cone. In diagram (5) there would be four high speeds from the speed cone and four low speeds driving through the back gears.

For high speeds, fasten the speed cone to gear D, which is fastened to the spindle.

For low speeds, disconnect speed cone from gear D, and engage the back gears. The speed cone then drives pinion A to gear B, through the sleeve to pinion C, then to gear D, which is fastened to the spindle.

Drilling in the lathe (diagram 2). Before starting to drill work in the lathe it is well to check the two marks on the tailstock, to make sure that the tailstock spindle is in alignment with the headstock spindle. If the tailstock is "offset", the drill will not be located on centre of the work and will therefore be sprung off centre. This will probably lead to the breaking of the drill.

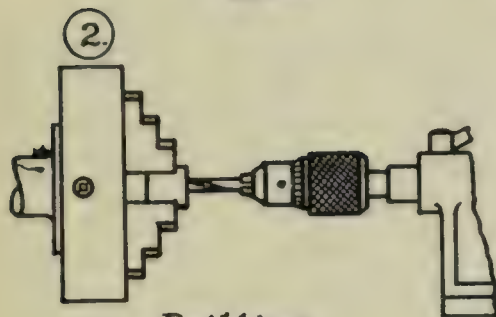
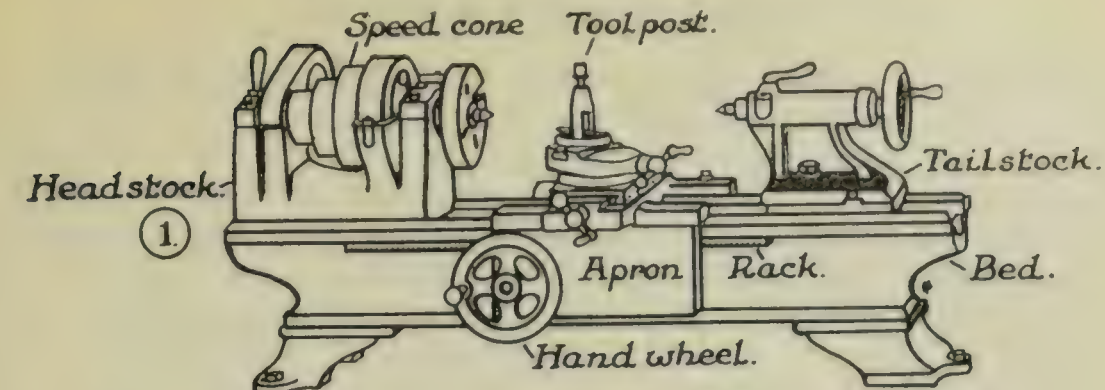
Tapping in the lathe (diagram 3). After drilling the tap drill size hole, as shown in diagram (2), the work should be tapped before it is moved in the chuck, so that the tapped hole will be in alignment. If a taper tap is well started in this way (the machine being operated by hand), it can be finish-tapped in a bench vise.

Turning angles (diagram 4). To turn angles, the carriage must be locked rigidly to the bed and one-half the required angle set on the graduations of the compound rest from the lathe centre alignment.

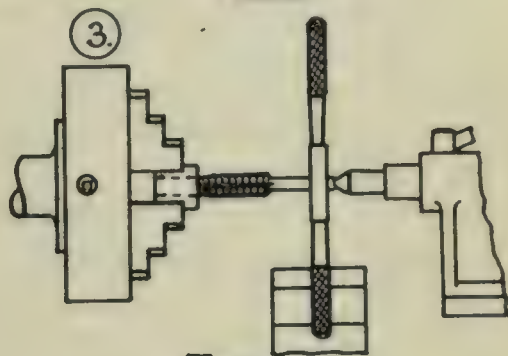
Example: To turn a 30 degree point on work, swing the compound slide 15 degrees from the lathe alignment.

Turning on centres (diagram 6). The advantage of turning work on centres is that the work can be taken out and put back in the

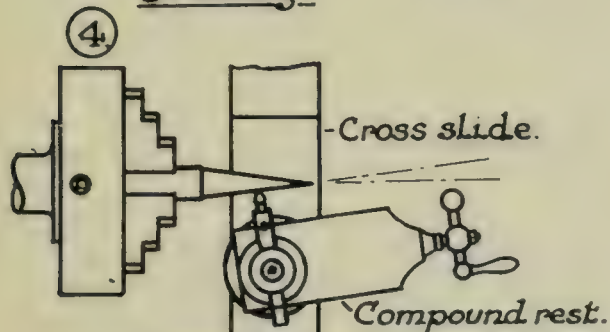
THE BENCH LATHE (Continued)



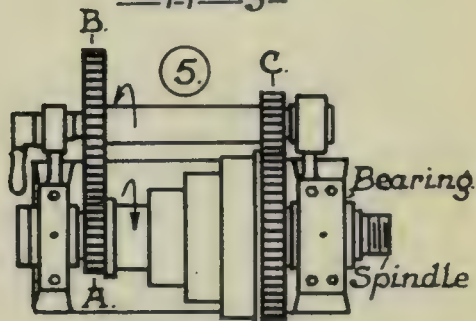
Drilling.



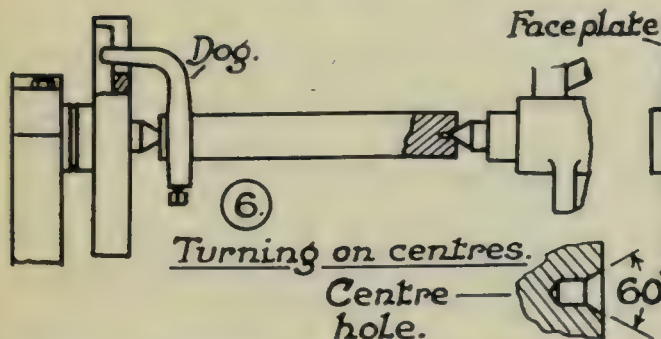
Tapping.



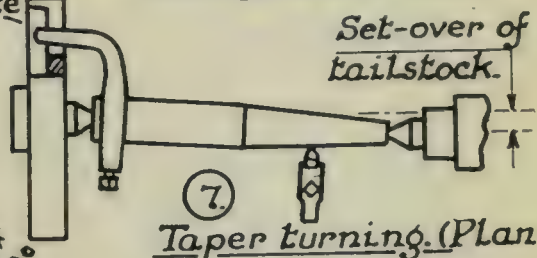
Turning angle.



Back gears. (Plan)



Turning on centres.



Taper turning. (Plan)

machine and it will always run true. With work held in the chuck, it is necessary for beginners to finish it at the first set-up.

Taper turning (diagram 7). The tailstock is offset or set over to the required amount calculated.

Example: a piece of work 6" long with a number 3 Morse taper .602" per ft.

$$\text{Set over} = \frac{\text{Taper in inches per. ft.}}{2} \times \frac{\text{length of work in inches}}{12}$$

$$\text{Set over} = \frac{.602}{2} \times \frac{6}{12} = \frac{.602}{4} = .150 +$$

$$\text{Set over} = .150"$$

Note: In this and subsequent "Questions" the pupil will perform the usual cancelling operations before multiplying.

MEASURING TOOLS

Measuring the diameter of work. The outside caliper shown in diagram (1) is a common tool used for this purpose. There is a tendency with beginners to force the calipers over the work, allowing the legs to spring apart, and thus giving the impression that the work is to size. An expert knows that the important thing in the use of calipers is the "feel". He can tell whether the work is out a few thousandths of an inch by the "feel" as the caliper passes over the work.

Setting outside calipers from the rule. This is shown in diagram (3). The accuracy of such a setting depends upon the eye and the fineness of the rule graduation. The calipers are tapped on the pivot end to open them slightly, and tapped on the bow of the leg to close them. By putting one leg against the end of the rule it is only necessary to set one leg to the graduation.

Measuring inside diameter. This is accomplished by the use of inside calipers, as shown in diagram (2). It is very important to keep the two ends of the legs at right angles to the axis of the work, as shown, otherwise the diameter of the bore will not be accurately measured.

Setting inside calipers. Place one leg against a metal block, as shown in diagram (5), with the rule also against the block, and set the other leg to the graduation.

Hermaphrodite caliper. This caliper has one straight leg and one bent leg, and can be used to mark the length of a piece of work from the end of the stock, as shown in diagram (4). It can also be used to mark parallel lines to an edge, or to locate the centre of a piece of stock.

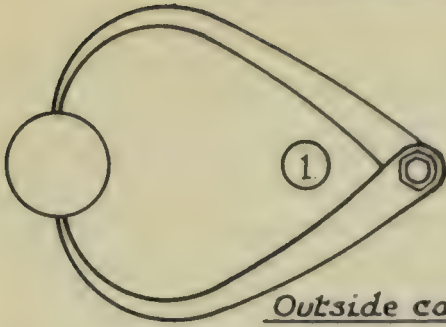
Centre gauge. The centre gauge (diagram 6) is used mostly to test the angles of lathe centres which are 60 degrees, but it can also be used for making small measurements in close places, for setting threading tools, and for testing the angles of a chisel face.

The slide calipers (diagram 7). This is a most convenient tool, as it reads a measurement direct, and can be used to test an outside diameter or an inside diameter, as shown in the sketch.

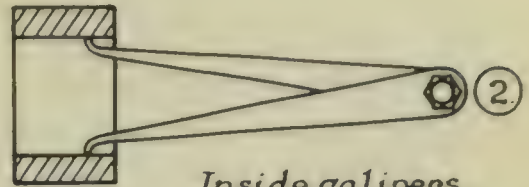
Measuring drills. A drill gauge (diagram 8) is a plate with a series of holes in it, with the sizes of the holes stamped on it. Sometimes the size of the drill is worn off the shank and it is advisable to check the drill before use in order to be sure of its size, as shown in the sketch.

Measuring depth. The depth gauge (diagram 9) is used to measure depth. The horizontal piece shown rests on the top of the hole. The screw is loosened and the graduated blade pushed down until it touches the bottom. The screw is then tightened and the depth of the hole noted on the graduated scale.

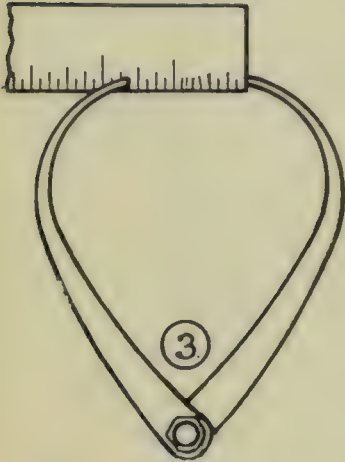
MEASURING TOOLS (Continued)



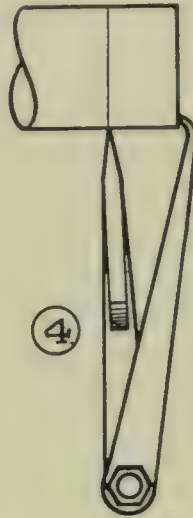
Outside calipers.



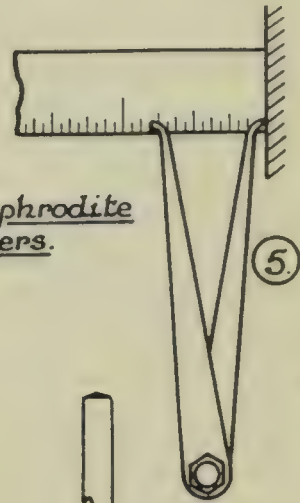
Inside calipers.



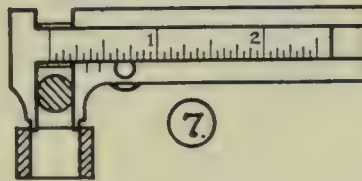
Centre gauge.



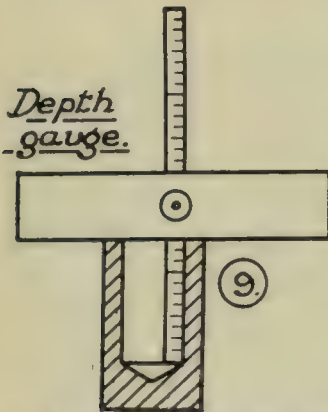
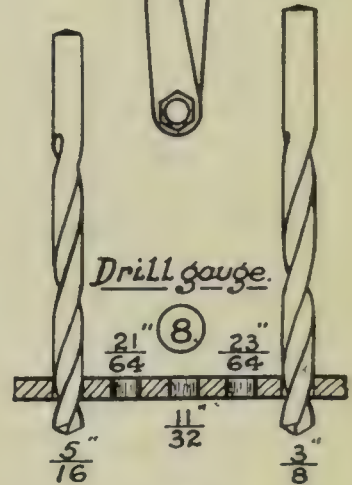
Hermaphrodite calipers.



Slide calipers.



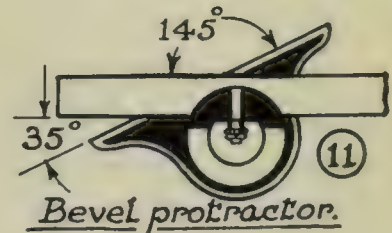
Drill gauge.



Depth gauge.



Centre head.



Bevel protractor.

Locating the centre of stock. This can be accomplished by use of the centre head fitted with a rule, which always bisects the angle of the head, as shown in diagram (10). One line is drawn through the diameter of the stock. The stock is then turned, and another line drawn. Where the two lines intersect is the centre of the stock.

Measuring and testing angles. The bevel protractor shown in diagram (11) is one tool used for this purpose. Graduations are provided to measure accurately in degrees, and the rule can be adjusted in or out to suit the conditions of the work.

SQUARING AND DRILLING IN THE LATHE

Squaring and drilling in the lathe are operations that often occur in lathe work, and are introduced to the beginner as the first cutting operation on the lathe.

The shape of the tool bit. When purchased, a tool bit is shaped as in diagram (3).

For average work the beginner will find the angles shown in diagram (1) suitable, but these angles may be varied according to the kind of work to be done and the kind of metal to be cut.

The tool-holder. The tool bit is held, when being used in a tool-holder, as shown in diagram (2). It provides a rigid support for the tool bit and allows for a vertical adjustment in the inclined slot into which the tool bit fits. Various shaped tool bits may be used with one tool-holder. By loosening the set-screw a change can quickly be made.

Rough-squaring rolled stock. When stock is sawn off on a power saw, it is not smooth or square with the axis of the stock. To square the stock, it can be held in a universal chuck and rotated against the stationary tool bit. The tool bit is placed on centre, as shown in diagram (5).

In plan, the cutting edge is slightly inclined, to under-cut as shown in diagram (4).

The operation of rough-squaring is best carried out by the beginner in a series of stepped cuts, each cut being made in the direction of the arrow marked "feed".

Finish-squaring. To "finish square", as shown in diagram (6), a light cut must be taken, and the tool bit moved by operation of the cross-slide in the direction of the arrow marked "feed". It is essential that the carriage be locked to the bed of the lathe, or held stationary with the left hand on the hand-wheel while the tool is cutting, otherwise the work will not be square.

Cutting speed. The cutting speed varies and increases as the tool moves outward. Therefore the cutting speed of the work must be calculated on the outside diameter of the stock.

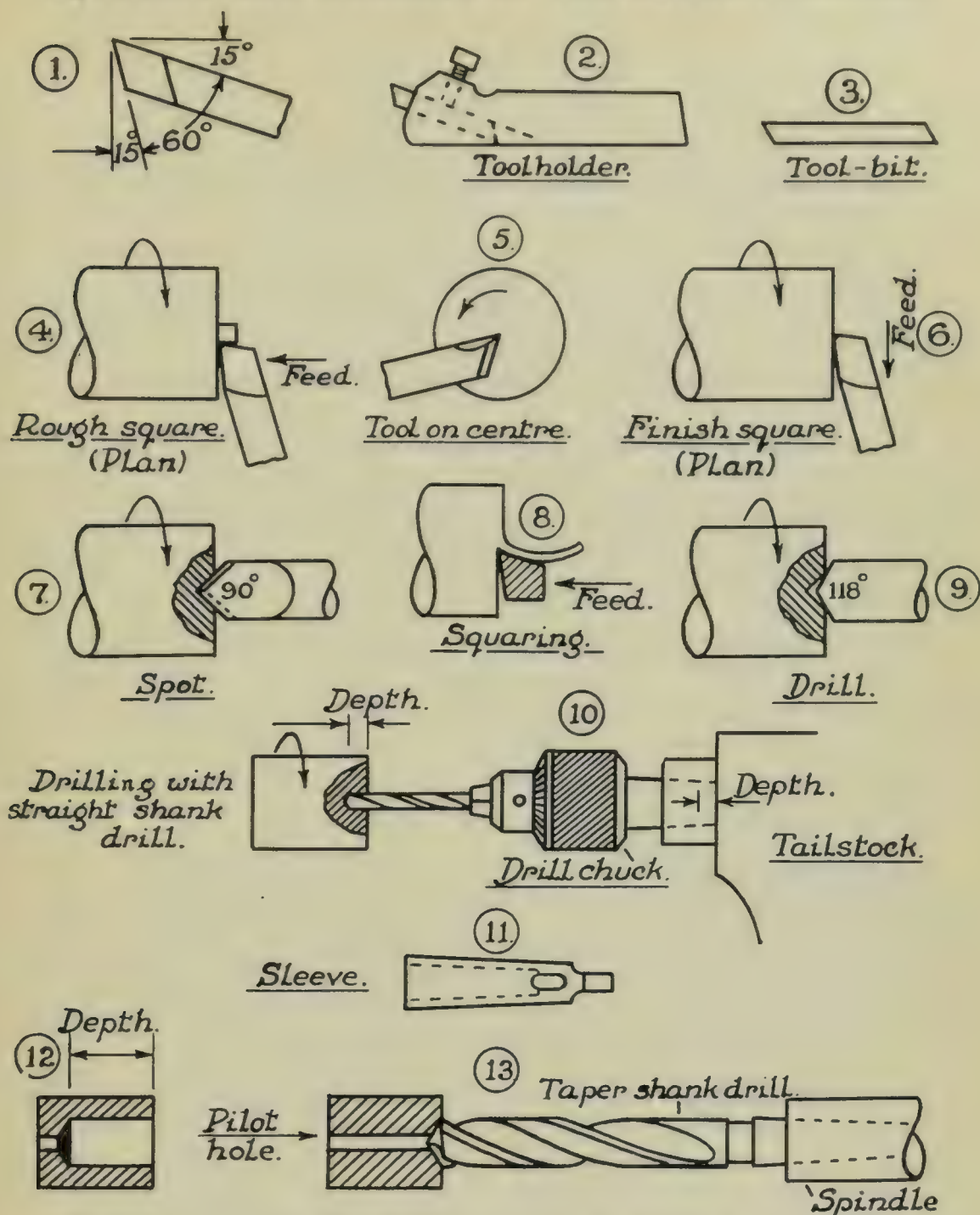
Cutting action. Diagram (8) shows how the metal is removed. The chip slides down on the inclined top face of the tool, with clearance shown on the side of the tool.

Drilling work in the lathe. Diagram (7) shows the first step in drilling. A spotting tool is used to cut a conic recess as a starting point for the drill. Without this "spot" a small drill would tend to spring off centre. Diagram (9) shows the drill starting to cut in the spotted recess. The angle of the drill, 118 degrees, allows it to contact on the sides of the conic recess and thus it follows the line of least resistance, which is the axis of the work.

Holding a straight shank drill. Diagram (10) shows a straight shank drill being held in a Jacobs Drill Chuck, fitted by a taper shank to the tailstock spindle. The depth of the drilled hole is measured by inside calipers or by a rule on the spindle, as shown.

Holding taper shank drills (diagram 13). A No. 3 Morse tapered shank fits exactly into a No. 3 Morse tapered spindle.

SQUARING AND DRILLING IN THE LATHE (*Continued*)



If the drill had a No. 2 Morse taper, it would be necessary to enlarge it with a sleeve (diagram 11). The sleeve would be No. 2 inside and No. 3 outside to fit a No. 3 spindle. A Morse taper used on a drill is $\frac{5}{8}$ of an inch per foot, approximately.

To measure the depth of a hole. A mark is placed on the tailstock spindle when the corner of the drill touches the face of the work (diagram 13).

The depth of the hole is measured, as shown in diagram (12).

A pilot hole diagram (diagram 13). This helps to speed up the cutting action of a large drill and keeps the drill cutting in line with the axis of the work.

CASE-HARDENING

Carbon tool steel (diagram 1) contains from 50 to 150 point carbon and if heated to its proper hardening heat, it hardens when quenched.

Machine steel (diagram 2) contains 35 point carbon, and if heated and quenched, as in example 1, it will still be soft. This is because it does not contain sufficient carbon, and is therefore not classed as a tool steel, being too soft for making tools.

Decarburizing tool steel. If a piece of tool steel (diagram 3) is heated for a long time by exposure to a fire, the carbon in the outer portion of the steel is burned out, or the steel is "decarburized". If the steel is quenched from a hardening heat, it will be noticed when tested with a file to be soft on the outside and hard on the inside.

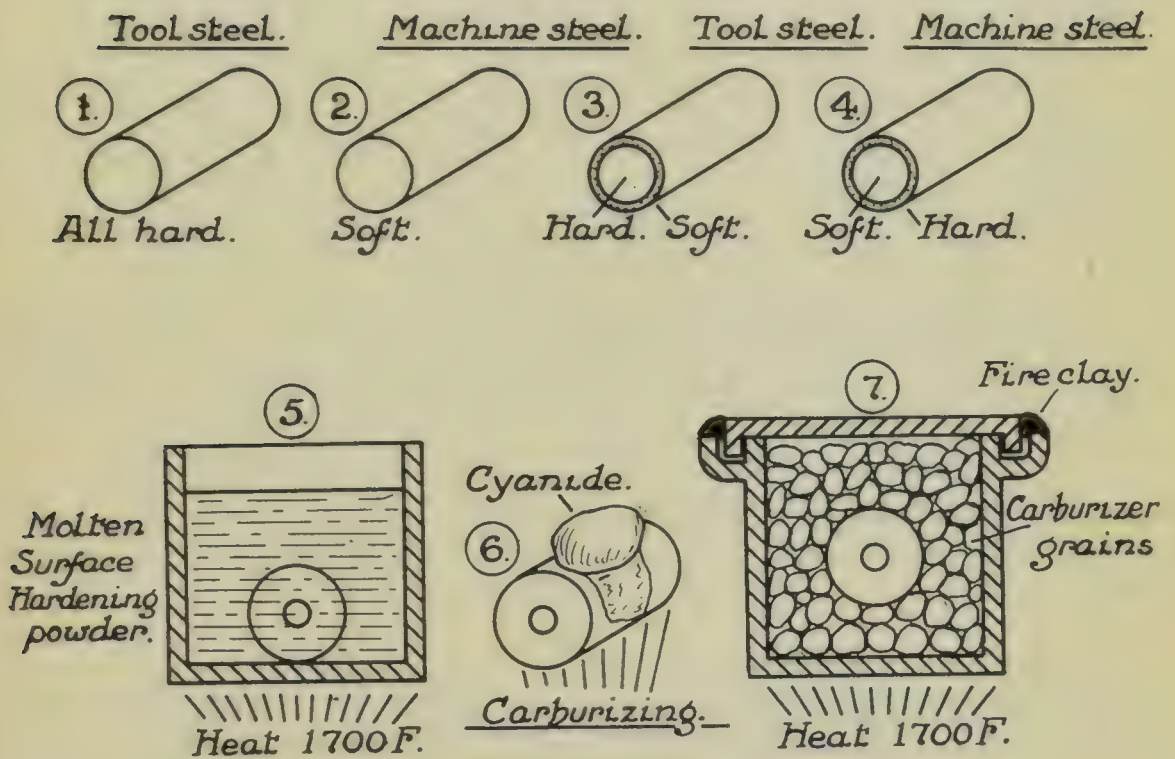
Carburizing and case-hardening (diagram 4). In this case a machine steel is treated with a substance rich in carbon, which is absorbed by the steel. This operation is called "carburizing" and is the first step to be taken in case-hardening. If the steel is then quenched from a hardening heat, it will be observed that the outside is file hard and the inside soft.

Methods of carburizing. (1) *Work immersed in a molten bath.* Surface-hardening powder, or cyanide of potassium, is melted in a pot and the work is heated in this molten bath. In this way it is kept from the air, thus preventing oxidation; and being away from the direct action of the fire, it cannot be decarburized. The low-carbon steel absorbs carbon best at a temperature of 1700 to 1800 degrees F.

(2) *By application of cyanide.* The work is heated, as in diagram (6), in a fire or with a torch, and the cyanide is applied. It readily melts and is absorbed by the steel. It is a quick method, but there is danger that it may be decarburized as fast as it is carburized, if it is kept too long in the fire, as in diagram (9), on page 85.

(3) *By pack-hardening process.* The work is placed between layers of carburizer grains, and is sealed up with a lid luted with fire-clay. This prevents any gases from escaping. The gas, nitrogen, given off by the carburizer, permeates the outer part of the steel, and if this method is used for six hours at 1700F., the steel will be carburized to a depth of 1/16".

CASE-HARDENING (Continued)



CASE-HARDENING (*Continued*)

Case-hardening. After the steel has been carburized, as in diagram (10), between the temperature of 1700F and 1800F, it is then treated as tool steel, which the outside has then become. The hardening heat of tool steel (diagram 8) is between 1420F and 1490F. If the carburized steel is then heated within this range of temperature and quenched in water (diagram 11), it will be case-hardened.

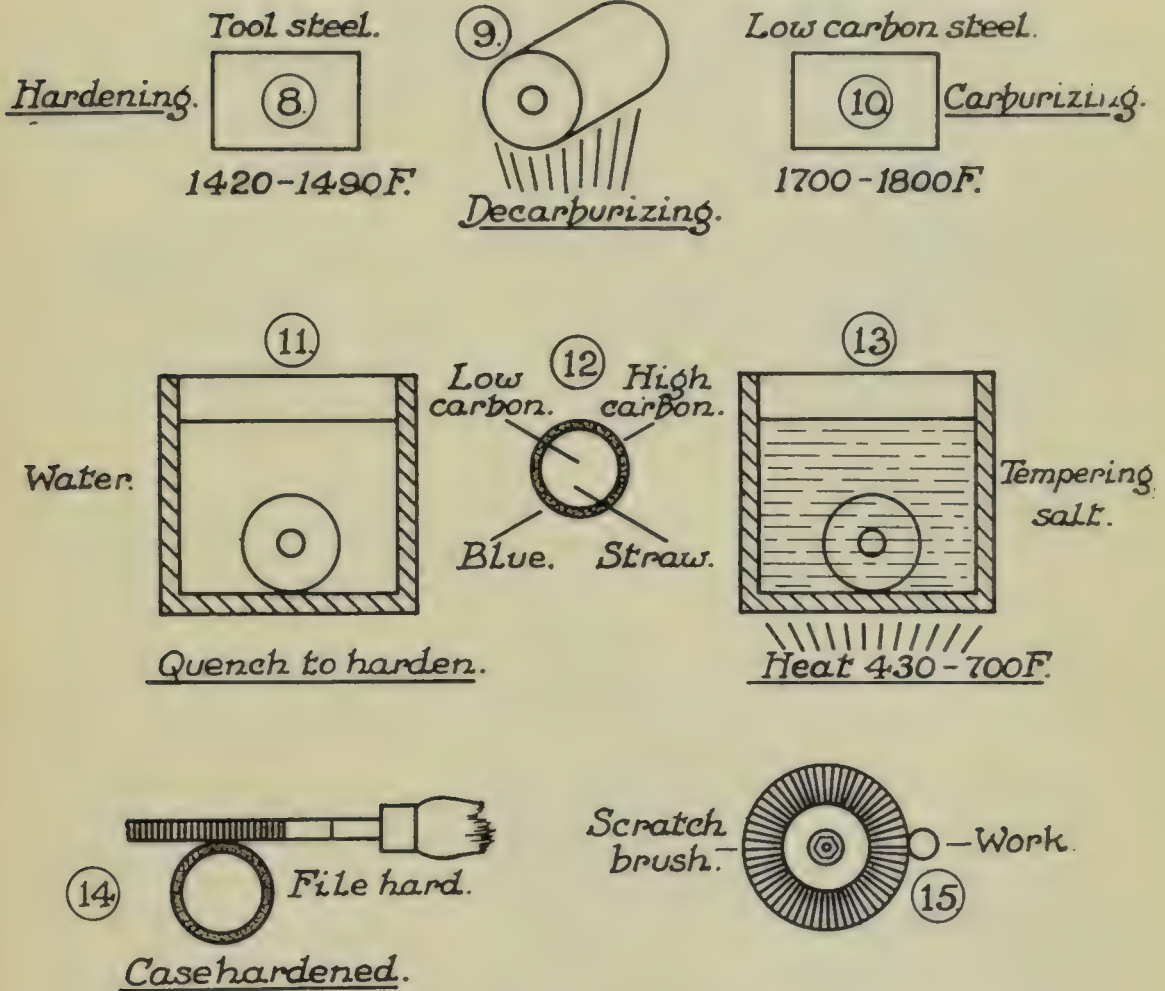
To show the depth of case (diagram 12). Polish the end of the sample and heat it slowly. As the steel oxidises, the outer case of high-carbon content will be blue, while the low-carbon core will be of a straw colour, thus showing clearly the depth the carburizer has penetrated.

Tempering after case-hardening. In some cases this is advisable. The work can be immersed in tempering salt, as shown in diagram (13), and heated to the required temper within the tempering range of 430F to 700F, according to the use the metal has to be put to.

Testing case-hardened work (diagram 14). Test work after case-hardening. To be certain that the case is hard, test with the heel of a file.

Cleaning case-hardened work. Unless the case is deep, it is well to use a scratch brush to clean case-hardened work, as shown in diagram (15). If the work must have an accurate fine finished surface, it cannot be cut with cutting tools, but it can be ground with an abrasive wheel. This is only possible when the case is deep. If work with a thin case is ground, all the hardened surface will be removed and it will not wear well in use.

CASE-HARDENING (Continued)



TAPPING AND THREADING

Tapping consists of cutting threads inside a drilled hole with a threaded tool made of carbon tool steel which has been hardened, tempered, and ground. Flutes are cut into a tap to provide the cutting edges and to allow the chips of metal cut off the work to pass out of the hole.

Tap drill size. A hole is first drilled in a piece of work before tapping it. A $\frac{3}{8}$ "-16 U.S.S. tap requires a $\frac{5}{16}$ " hole to be drilled. These sizes can be found by looking up a tap drill size table (see page 108).

The taper tap (diagram 1) is the first tap to be used in tapping any hole. The end of the tap is tapered to allow it to enter the hole and cut the thread gradually. Be sure that the tapered part of the tap passes completely through the hole so that full threads are cut entirely through the work, as shown in diagram (1).

Tapping in the vise. The tap is turned by means of a tap wrench (diagram 2). If the tap wrench is too big, there will be too much leverage and this may cause the tap to be broken. Advance a quarter of a turn and then reverse the action and keep the tap well covered with a cutting oil, such as lard oil. Keep the tap at right angles to the work, otherwise the hole will be tapped "out of line".

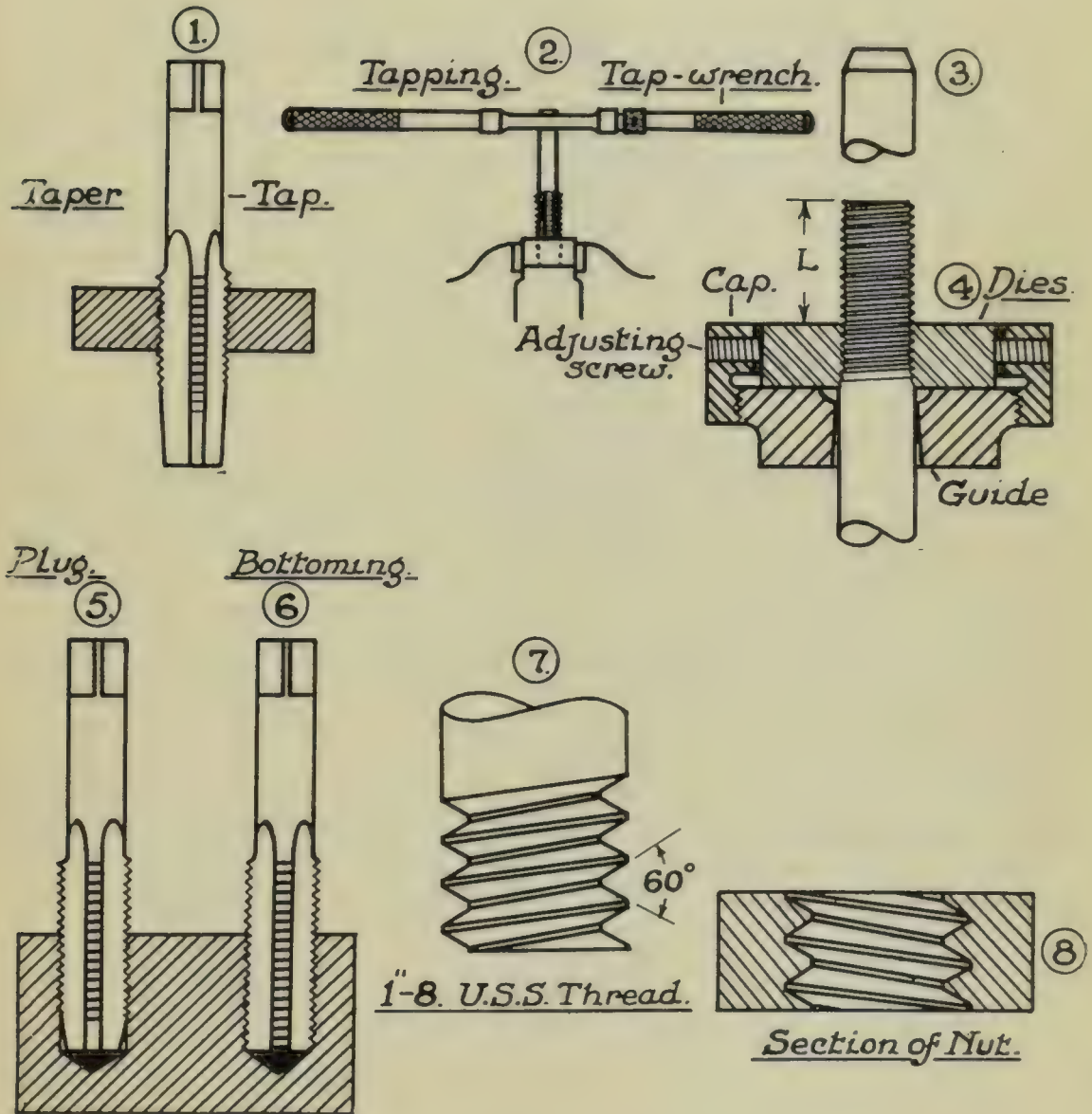
Tapping a blind hole (diagrams 5 and 6). Start the tapping with a taper tap; then follow with a plug tap (diagram 5), and finish the threads to the bottom of the hole with a bottoming tap (diagram 6).

Threading with a die (diagram 4). The work should first be chamfered, as shown in diagram (3), to give the die an easy start. The guide steadies the die at right angles to the axis of the work. The lower part of the dies are tapered to cut the thread gradually, so that the work is only perfectly threaded when it protrudes from the top of the dies. The length of threaded work should be measured, as marked at L. The dies can be adjusted in or out to make the diameter of threaded work larger or smaller than its nominal size.

A United States Standard thread (diagrams 7 and 8). This thread is usually represented as shown in the diagrams. A 1"-8 U.S.S. thread means that it is one inch in diameter and has 8 threads per inch and is United States Standard shape, which has a 60 degree angle and is flat, top and bottom, an amount equal to $\frac{1}{8}$ of its pitch.

The pitch of a thread is the distance from the top of one thread to the top of the next thread.

TAPPING AND THREADING (Continued)



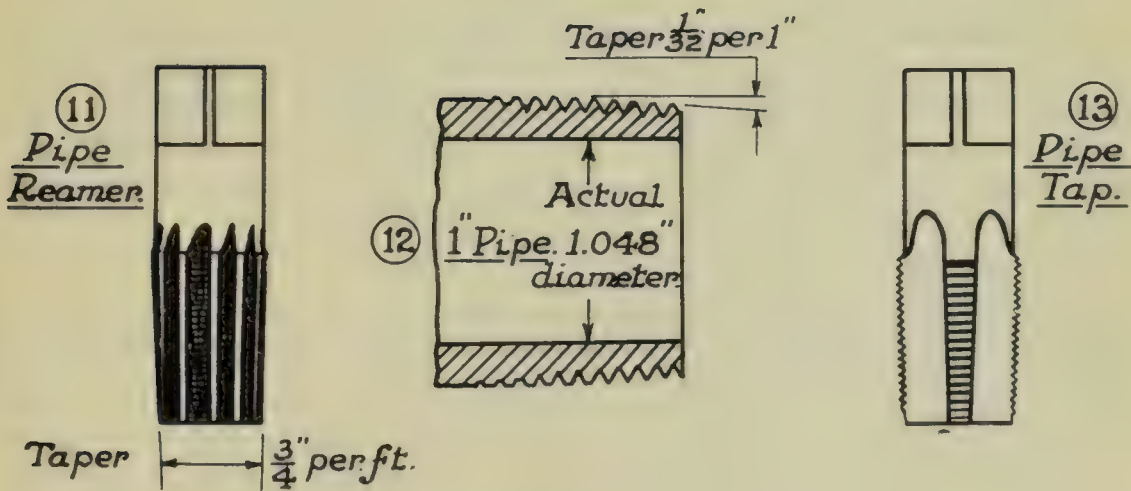
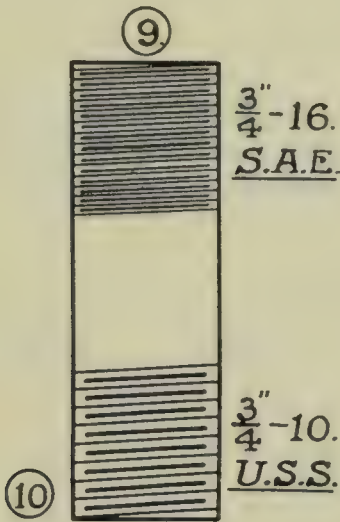
TAPPING AND THREADING (*Continued*)

Coarse and fine threads (diagrams 9 and 10). Both these threads are cut on a piece of stock $\frac{3}{4}$ inch in diameter. The upper threads are fine as compared with the lower ones. S.A.E. means Society of Automotive Engineers, and is the standard thread used on automotive work. The United States Standard thread is used on all general engineering work in the United States and Canada. Both S.A.E. and U.S.S. threads are of the shape shown in diagram (7), on page 87. This shape is known as the sellers or United States thread form.

Pipe thread. American or Briggs standard pipe thread is illustrated in diagram (12). It is a tapered thread, $1/32$ per inch from the inside bore or $\frac{3}{4}$ per ft. included angle for the pipe. The pipe thread when engaged seals the joint so that it will withstand the pressure of water or steam. Large-sized holes are first reamed to the correct taper with a pipe reamer, shown in diagram (11). The pipe tap (diagram 13) is then used to tap the hole. Pipe dies are also tapered and are used in a similar fashion to the dies shown in diagram (4), on page 87.

Pipe sizes. Pipe is measured by its bore size. Diagram (12) shows a one inch pipe measured inside the bore of the pipe. The actual diameter is always slightly greater than the nominal size. For example, a one inch pipe measures inside 1.048 inches.

TAPPING AND THREADING (Continued)



FORGING

Forging is a method of shaping or joining metal with the aid of heat. It is particularly suitable for wrought iron; but tool steel must be operated on with great care.

This lesson deals chiefly with the bending and shaping of metal, as welding is too difficult for the beginner.

The anvil (diagram 2) is the most important equipment used in forging. It is made of wrought iron or mild steel, and its upper face is protected by a hard face of cast steel, which is welded on. The face is slightly round for the same reason that a hammer face is rounded to enable the operator to strike a solid blow. A square hole is provided into which the hardie or swages are fitted, and a round hole is provided for punching. The small flat face adjoining the beak or horn of the anvil is made of soft iron. It is provided so that the operator can cut metal on it without damaging the steel face of the anvil. The horn is used for bending work, such as is shown in diagrams (14) and (15), on page 93.

Cutting metal. Metal can be cut hot or cold. If the metal is hot, it is cut part of the way through on the soft part of the anvil, with the hot chisel or hot set shown in diagram (1). It is then struck with a hammer in the direction of the arrow to break it off.

To cut metal cold, it is rested on the soft block of the anvil and cut around (as shown in diagram 3) with a cold chisel or cold set, and is then broken off. If the cold chisel is used for hot work, the temper will be drawn and it will then be impossible to use it for cutting cold work until it is again hardened and tempered.

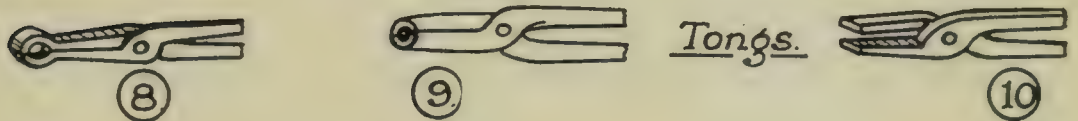
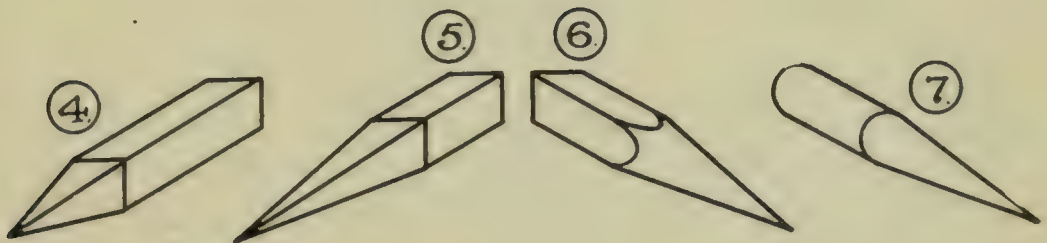
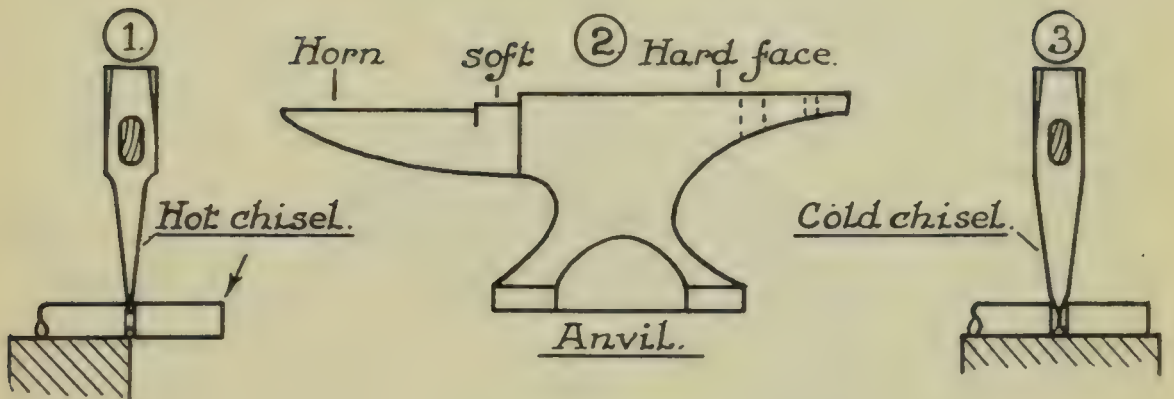
Forging a point. In drawing out a point the metal should be drawn out to a short pyramid point first, as shown in diagram (4). This is followed by further drawing back to the required length (diagram 5). In forming a conical point on square or round stock it is advisable first to form a square point and then to round off the corners. If this is not done, the metal will split or form a hollow at the point called "piping".

Heat required. For wrought iron and mild steel, forge a point while the metal is at a white heat. For tool steel, the metal should not be heated beyond a red heat, otherwise the steel will have a coarse grain structure, and will crumble under the hammer blows.

Tongs used for forging. The pick-up tongs shown in diagram (8) are very useful to hold small round pieces and are generally useful for picking up and holding light work. The hollow bit tongs (diagram 9) are used for holding round or octagonal pieces of metal while bending or forging the metal.

The flat open mouth tongs (diagram 10) are suitable for holding flat metal whose thickness does not exceed the distance between the jaws when they are parallel.

FORGING (Continued)



FORGING (*Continued*)

The section of a forge fire (diagram 12). This shows a forge fire made up from blacksmith's coal, which is a soft bituminous coal. The Tuyere is a casting, through which the blast enters the fire. The coke in the centre section A is the fuel used, and around it the soft wet coal is "banked". The heat from the centre section A turns the adjacent green coal into coke at B, while it is surrounded by wet coal at C. Keep the fire deep and place your work away from the blast, as shown.

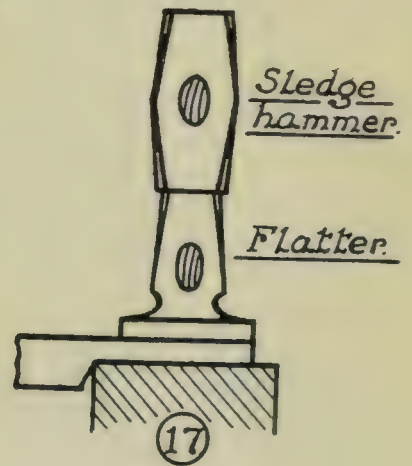
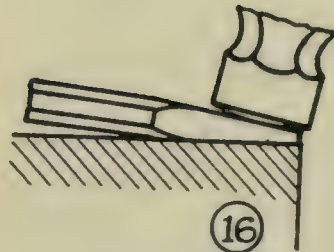
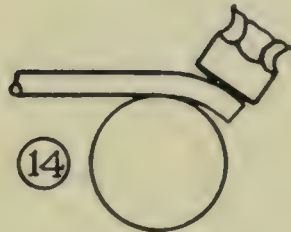
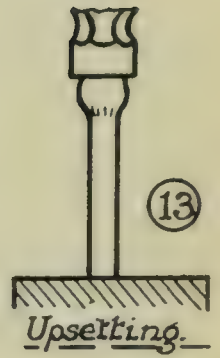
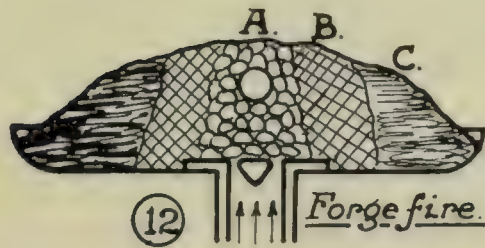
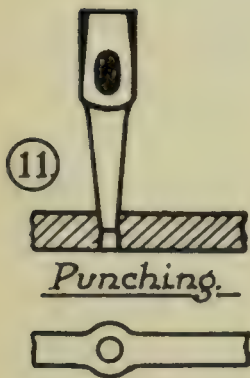
Punching. Holes can be punched half way through from each side of a piece of metal, which produces a hole as shown in diagram (11), without reducing the original area of the metal, as would be the case if a hole were drilled.

Upsetting (diagram 13). Metal can be "upset" or enlarged by heating wrought iron to a white heat and striking the end with a hammer. Keep the lower part cool and straighten the metal when necessary.

Forging a flat surface. If the work is tapered, as in a chisel point (diagram 16), keep it near the edge of the anvil, so that the tool steel face of the hammer will not strike the tool steel face of the anvil and damage both. Surfaces are finished flat by use of a flatter (diagram 17), which is struck a blow with a sledge hammer to produce a flat surface.

Bending metal hot. When metal is bent hot, care must be taken not to strike a blow with the hammer when the part of the metal struck is against the horn of the anvil, or it will be hammered thin. The correct method is shown in diagrams (14) and (15), the hammer striking the metal while it is away from the horn and bending it down towards it.

FORGING (Continued)



TURNING TO DIAMETER

Tools for ferrous metals. There is a similarity among cutting tools used in the separation of metal. Diagram (1) illustrates the three angles of a tool bit. A is called "front rake", B the "front cutting angle", and C the "front clearance". If these angles are compared with a twist drill (diagram 2), it will be seen that the same angles are used.

Tools for a non-ferrous metal. Tools for brass differ from the tools used for ordinary ferrous metals, as shown in diagrams (1) and (2). The brass tool for lathe-work, shown in diagram (4), has no front rake, nor has the drill shown in diagram (5), because brass tends to pull the tool into itself, and by removing front rake on the tool this tendency is prevented.

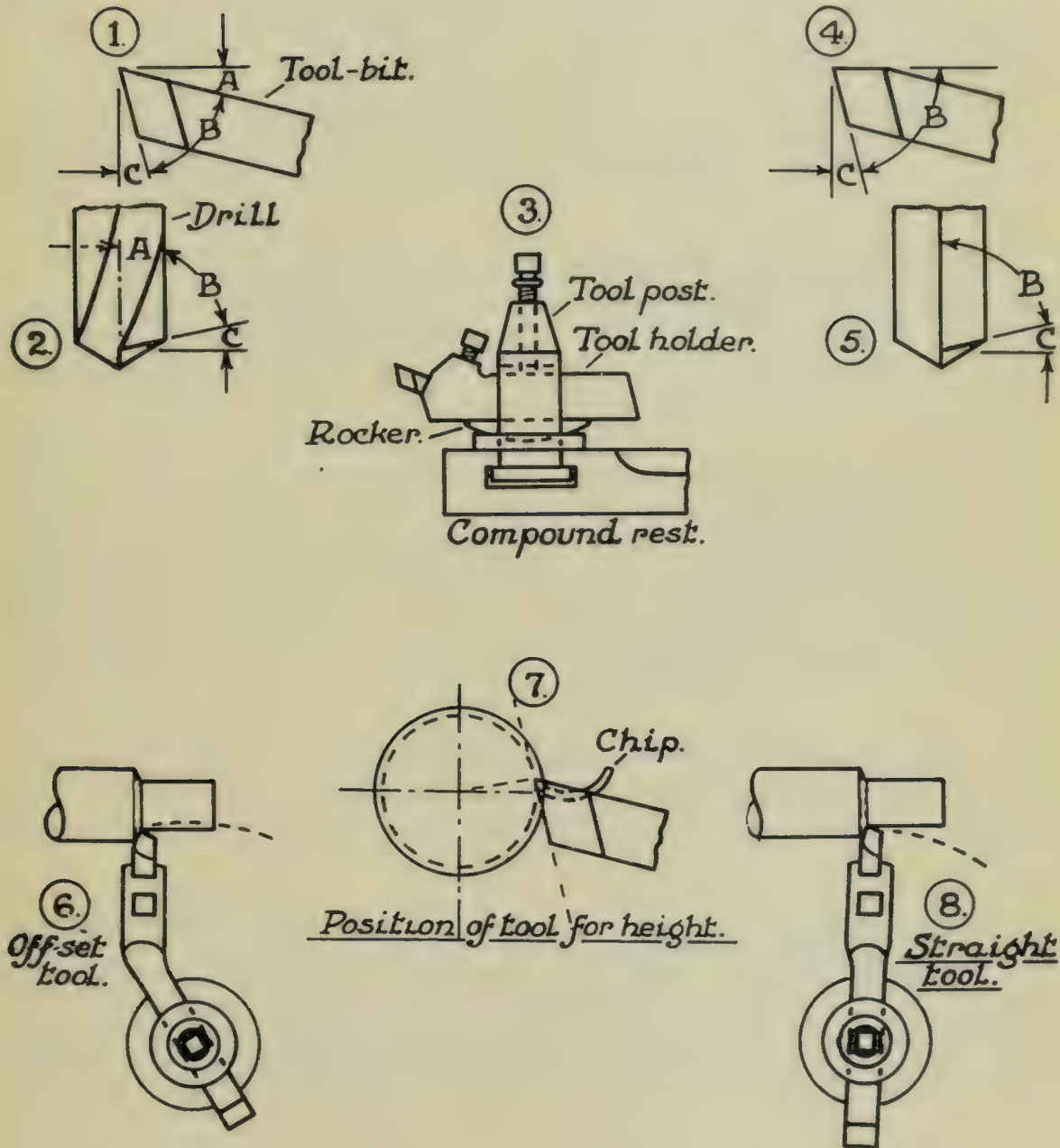
Lathe tool-post. The tool-post (diagram 3) is the holding device for the tool-holder. It provides a means for holding the tool in any position, as it can be turned around in a horizontal plane. The rocker swivels in a concave base and provides a vertical adjustment for the tool-holder. The tool-post is secured in the tee-slot of the compound slide rest and can be moved in the slot to the most convenient position, which is usually near to the headstock side of the slide.

Use of an offset tool-holder. Diagram (6) shows an offset tool-holder turning work held in a chuck. This tool allows the operator to work up close to the chuck jaws without fear of the jaws striking the compound rest. The disadvantage of this tool is that under pressure of the cut, if it turns, as shown by the dotted line, the work will be spoiled.

Position of tool for height in turning. Diagram (7) shows the best position for turning metal. The front of the tool should be at a tangent with the finished diameter of the work. This position usually places the tool point about 5 degrees above the centre of the work.

Turning with a trailing action. This is illustrated in diagram (8) by a straight tool-holder. Under pressure of the chip the tool-holder would tend to turn around on the centre of the tool-post, thus moving away from the surface of the work, making it larger. In addition to this, "chatter" is prevented and a smooth surface on the work results.

TURNING TO DIAMETER (Continued)



TURNING TO DIAMETER (*Continued*)

Depth of cut. This is illustrated in diagram (9). A $\frac{1}{8}$ " depth of cut means that a one inch diameter piece of stock is reduced by $\frac{1}{4}$ inch to a $\frac{3}{4}$ inch diameter.

Feed of the tool (diagram 9). This represents the amount the tool travels along the work parallel to its axis in one revolution of the work.

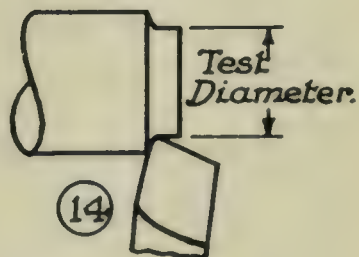
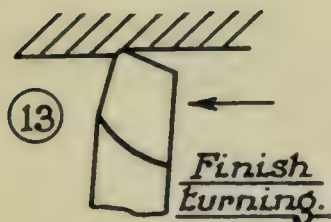
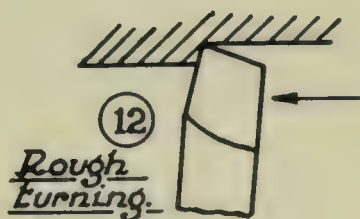
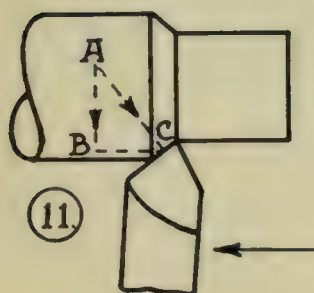
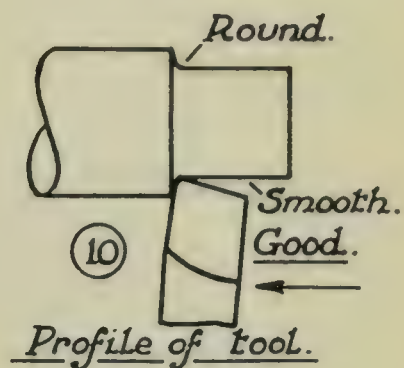
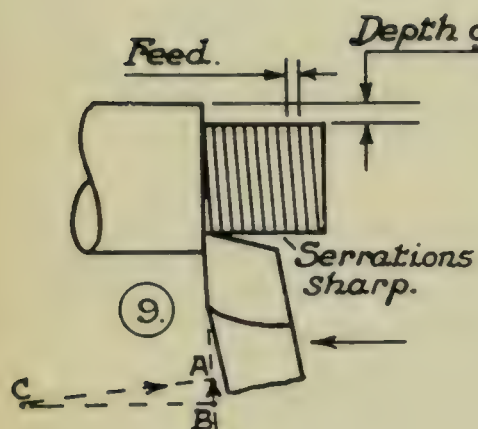
Types of tool bits in profile (Plan). Diagram (9) shows a sharp pointed tool bit, which produces a sharp serrated surface on the work. This is very bad. If the point of the tool bit is rounded off slightly, as shown in diagram (10), a smooth finish will be produced on the work.

Effects of forces on the tool. The direction of the force CA (diagram 9) has a vertical component BA, which tends to force the tool towards the axis of the work to further reduce its diameter. The direction of the force AC (diagram (11) has a vertical component AB, which tends to force the tool away from the surface of the work. If the work is of small diameter, it will compel it to bend and thus spoil it.

Rough turning (diagram 12). Work should be rough-turned with a maximum cut, just leaving the work slightly oversize. There is no reason for taking two light cuts when one cut will do it in half the time.

Finish turning (diagram 13). A finish cut is taken on work with a light cut to produce round accurate work and to obtain a smooth finish. It is well to test the diameter of work, in rough or finish turning, as soon as it is possible to measure it, as shown in diagram (14). Use a cutting compound to produce a smooth finish on the work.

TURNING TO DIAMETER (Continued)



CUTTING SPEEDS

Metals used for cutting tools. If a carbon steel tool, as shown in diagram (1), is used to turn work beyond the recommended cutting speed, the point of the tool will be overheated. This will "draw the temper", or take out its hardness, and the tool will not cut. To increase the speed of cutting metal, High Speed Steel was discovered. Metals of high melting point, such as tungsten, molybdenum, manganese, vanadium and chromium, were alloyed with carbon tool steel to form High Speed Steel. Diagram (2) shows a tool bit made of High Speed Steel, cutting work at twice the speed of carbon tool steel.

To-day a new cutting metal called Cemented Tungsten Carbide has been adopted for cutting metal at four times the speed of High Speed Steel, as shown in diagram (3). This metal consists of tungsten carbide (which is very hard, but brittle), cemented in cobalt. It is very expensive, and is used by brazing a small piece of it to the tip of a tough steel tool.

Comparative production by use of various cutting steels. The squares below the diagrams (1, 2 and 3) show the approximate amounts of work produced by the various cutting tools, carbon tool steel (1), high speed steel (2) and cemented tungsten carbide (3).

To find the cutting speed of work turned in a lathe (diagram 4: work one inch diameter). In one revolution the circumference of the work passes the tool point. If the work makes 280 R.P.M. (rev. per minute), then $280 \times$ the circumference passes the tool point in one minute. Cutting speed is usually expressed in feet per min. (f.p.m.); therefore if the work diameter is measured in inches, it is necessary to divide by 12 to bring it to feet.

Expressing this as an equation:

$$\text{C.S.} = \frac{\pi D \times \text{R. P. M.}}{12} = \frac{22}{7} \times \frac{1}{12} \times 280 = \frac{220}{3}$$

$$\text{C.S.} = 73.33 \text{ f.p.m.}$$

Note: In this and subsequent "Questions" the pupil will perform the usual cancelling operations before multiplying.

Question: What R.P.M. should a $\frac{3}{4}$ " dia. piece of machine steel make to be cut at a cutting speed of 80 f.p.m. with a high speed steel tool bit?

From equation in example above.

$$\text{R. P. M.} = \frac{\text{C.S.} \times 12}{\pi D}$$

$$\text{R. P. M.} = \frac{80 \times 12}{\frac{22}{7} \times \frac{3}{4}} = 80 \times 12 \times \frac{7}{22} \times \frac{4}{3} = \frac{4480}{11}$$

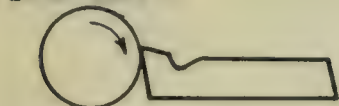
$$\text{R. P. M.} = 407.27$$

Cutting speed of a drill made of carbon tool steel (diagram 5). Material to be drilled is machine steel.

The work is stationary, and the drill rotates. Calculate the speed

CUTTING SPEEDS (Continued)

100 R.P.M.



①



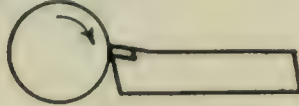
200 R.P.M.



②



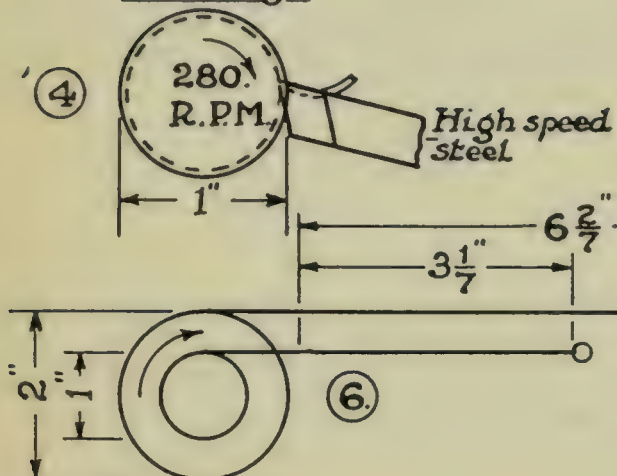
800 R.P.M.



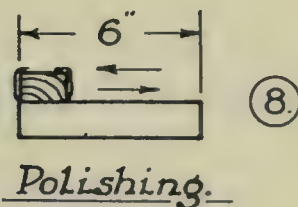
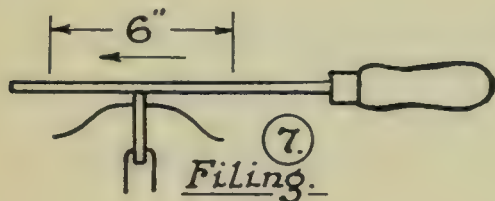
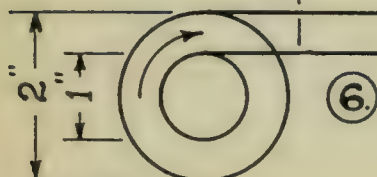
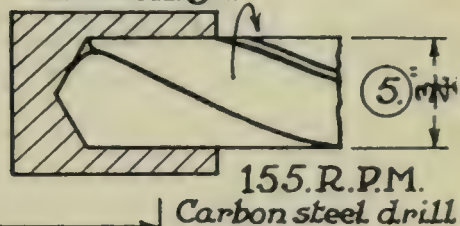
③



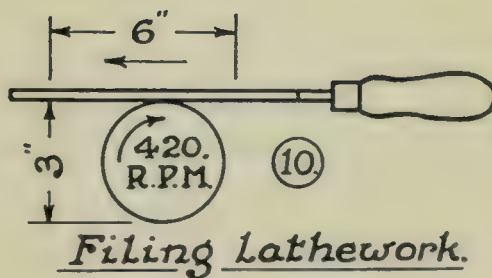
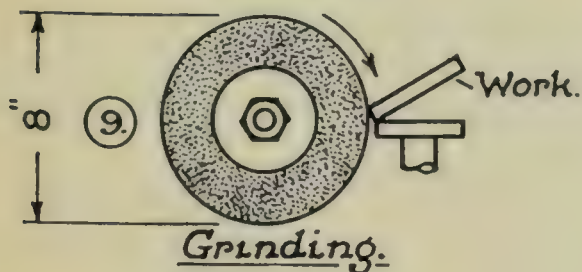
Turning.



Drilling.



2381 R.P.M.



for the outside diameter of the drill, which makes 155 R.P.M., and is $\frac{3}{4}$ " diameter.

$$C.S. = \frac{\pi D \times R.P.M.}{12} = \frac{22}{7} \times \frac{3}{4} \times \frac{155}{12} = \frac{1705}{56}$$

$$C.S. = 30.4 \text{ f.p.m.}$$

Experiment to show relative cutting speed (diagram 6). If string is wound around a piece of work having one diameter twice that of the other diameter, it will be observed, when the stock is rotated and the string unwound, that the length of the strings (representing two chips being removed from the metal) will be in proportion to the diameters of the work.

R.P.M. to give a constant cutting speed (example, diagram 6). It will be necessary for the small diameter to run at twice the speed of the larger diameter when being turned in order to give the same cutting speed in f.p.m.

Cutting speed of a file (diagram 7). The file is shown filing a piece of metal in the vise. It cuts only on the forward stroke. If the file makes 60 forward strokes and 60 return strokes in one minute, and if the length of the stroke is 6", then the cutting speed

$$= 60 \text{ strokes in } \frac{1}{2} \text{ minute}$$

$$C.S. = 120 \text{ " " 1 "}$$

$$C.S. = 120 \times \frac{6}{12}$$

$$C.S. = 60 \text{ f.p.m.}$$

Cutting speed of abrasive cloth (diagram 8). The abrasive cloth is wrapped around a piece of wood and is rubbed backwards and forwards on the surface of the metal, giving a continuous cutting action. If the cloth makes 60 forward and 60 return strokes in one minute, and the length of the stroke is 6", then the cutting speed

$$= 120 \times \frac{6}{12} = 60 \text{ f.p.m.}$$

Cutting speed of a grinding wheel (diagram 9).

$$C.S. = \frac{\pi D. \times R.P.M.}{12} = \frac{22}{7} \times \frac{8}{12} \times 2381 = \frac{104764}{21} = 4988.7 \text{ f.p.m.}$$

Question: What R.P.M. should a grinding wheel 7" diameter run at, to give a cutting speed of 5000 f.p.m.?

$$R.P.M. = \frac{C.S. \times 12}{\pi D} = 5000 \times 12 \times \frac{7}{22} \times \frac{1}{7} = \frac{30000}{11}$$

$$R.P.M. = 2727.2$$

Cutting speed of lathe-work being filed (diagram 10). It has already been shown that a file cuts only on the forward stroke; so that if the forward and return strokes of the file take equal time, one-half the total time is devoted to cutting.

The speed of cutting lathe-work will equal the peripheral speed of the work plus the speed of the file.

C.S. of work for a stationary tool (diagram 10)

$$C.S. = \frac{\pi D \times R.P.M.}{12} = \frac{22}{7} \times \frac{3}{12} \times 420 =$$

$$C.S. = 330 \text{ f.p.m.}$$

$$\text{Speed of file} = 60 \text{ f.p.m.}$$

$$\text{Total cutting speed} = 390 \text{ f.p.m.}$$

PULLEY AND GEAR SPEEDS

Diagram (1) illustrates a simple pulley drive. A pulley 10 inches in diameter is connected to a pulley 5 inches in diameter by means of a belt. If the belt does not slip when running, it illustrates in a practical way the meaning of an *Equation*. The amount of belt required to contact with the circumference of the large pulley is shown as $3\frac{1}{7} \times \text{diameter}$ or $3\frac{1}{7} \times 10$. The amount of belt required to contact with the circumference of the small pulley is shown as $3\frac{1}{7} \times 5$ inches. For the small pulley to have contact with the same amount of belt as the large pulley it is apparent that it would have to rotate twice while the large pulley rotates once.

From this one can see that the speeds of pulleys in a simple pulley drive are inversely proportional to their diameters.

The equation stated in diagram (10) is proved to be true, so that we can apply this to a problem.

Question: A motor runs at 1200 R.P.M. and has a pulley 4 inches in diameter, which is connected by belt to a machine with a 6 inch pulley. Find the speed of the machine.

(Follower)	(Driver)
$s \times d$	$= S \times D$
$s \times 6$	$= 1200 \times 4$
s	$= \frac{1200 \times 4}{6}$
s	$= 800 \text{ R.P.M.}$

The speed cone (cone pulley or stepped pulley, diagram 2) is provided on a machine to give speed changes, by moving the belt from one step of the cone to another. If shaft A runs at 500 R.P.M., find the speed of shaft B, if the belt is on the first step, as shown in diagram (2).

(Follower)	(Driver)
$S \times d$	$= S \times D$
$S \times 3\frac{1}{4}$	$= 500 \times 7\frac{3}{4}$
s	$= \frac{500 \times 7\frac{3}{4}}{3\frac{1}{4}}$
s	$= 500 \times \frac{31}{4} \times \frac{4}{13}$
s	$= 1192.3 \text{ R.P.M.}$

Question: Find the speeds of the follower stepped pulley B when the belt is moved on to each step of the pulleys (compound pulley drive, diagram 3). Pulleys A and C are drivers, and pulleys B and D are followers. Find the speed of pulley D, if pulley A makes 1200 R.P.M.

From the equation stated below, diagram (3).

$$S \times D \times D = S \times F \times F$$

$$1200 \times 6 \times 6 = S \times 12 \times 12$$

$$S = \frac{1200}{12} \times \frac{6}{12} \times 6$$

$$S = 300 \text{ R.P.M.}$$

Question: What size of pulley would be required at D to make the last follower shaft run at 700 R.P.M. if the first driver A runs at 1200 R.P.M., and the pulleys A, B and C remain the same as in diagram (3)?

$$S \times D \times D = S \times F \times F$$

$$1200 \times 6 \times 6 = 700 \times 12 \times F$$

$$F = \frac{1200 \times 6 \times 6}{700 \times 12} = \frac{36}{7}$$

$$F = 5 \frac{1}{7} \text{ inches}$$

Simple gear drive (diagram 4). Teeth are cut into gears to give a positive drive. Diagram (4) shows the two pitch circles of the gear and pinion in contact. With such a friction drive, slip would take place; so teeth are provided to prevent slip. When measuring gears, one should remember that the diameter of the pitch circles only have the correct ratio of the drive. The illustration shows a two to one ratio drive, the pitch diameters being 5 inches and 10 inches respectively.

The addendum is added to the pitch circles, which would be 1/10 inch for a 10 diameter pitch gear, making the outside diameters 5.2 inches and 10.2 inches, which is not a two to one ratio.

To find gear ratios, count the number of teeth. Pinion A has 50 teeth and gear B 100 teeth. If pinion A makes 100 R.P.M., find the speed of gear B. From the equation given beneath, diagram (4):

$$s \times t = S \times T$$

$$100 \times 50 = S \times 100$$

$$S = \frac{100 \times 50}{100}$$

$$S = 50 \text{ R. P. M.}$$

Compound gear drive (diagram 5). The diagram shows the plan of a lathe headstock, with the speed cone fastened to the pinion and running free on the spindle. The equation for a compound gear drive is similar to the one given for a compound pulley drive, except that the number of teeth replaces diameter as follows: Speed of first driver $\times$ number of teeth of all drivers equals speed of last follower $\times$ number of teeth of all followers.

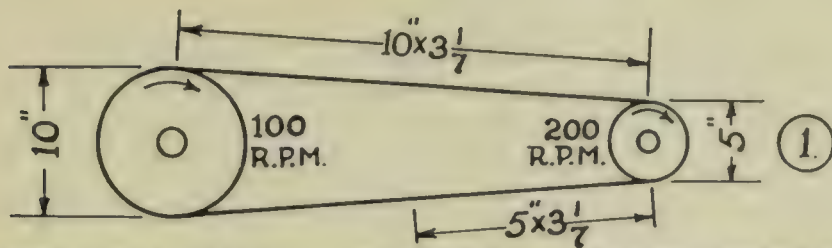
Applying this equation to diagram (5): If the speed cone makes 250 R.P.M., find the speed of the lathe spindle.

$$\begin{array}{cc} \text{(Drivers)} & \text{(Followers)} \\ s \times n \times n = S \times N \times N \\ 250 \times 30 \times 30 = S \times 75 \times 75 \\ S = \frac{250 \times 30 \times 30}{75 \times 75} \\ S = 40 \text{ R. P. M.} \end{array}$$

Question: If the speed cone in diagram (5) were of the same size as that shown at B, diagram (2), and run at 500 R.P.M., find the speeds of the lathe spindle with the back gears engaged, if the belt is moved on each step of the cone pulley.

Note: Four speeds are required.

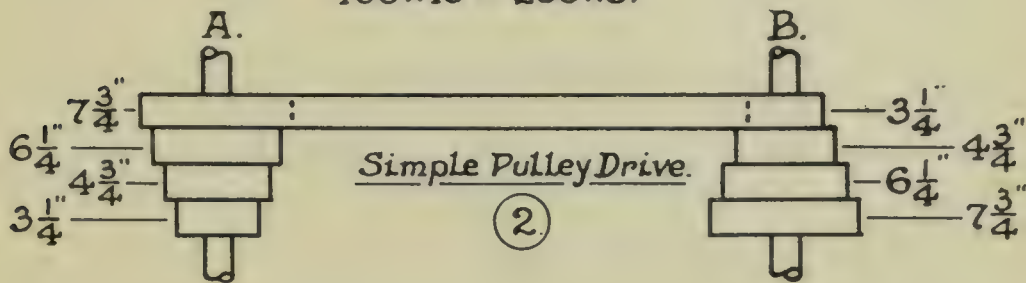
PULLEY AND GEAR SPEEDS (Continued)



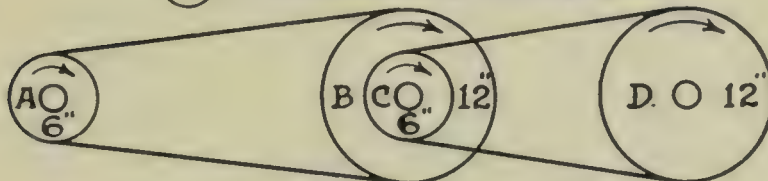
SPEED X DIAMETER. OF DRIVER. EQUALS SPEED X DIAMETER. OF FOLLOWER.

$$S \times D = s \times d.$$

$$100 \times 10 = 200 \times 5.$$

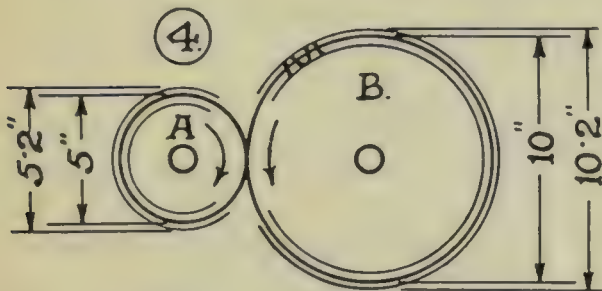


③ Compound Pulley Drive.

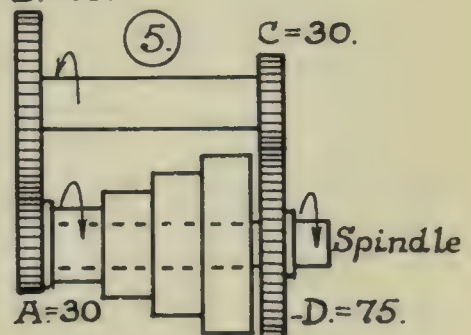


SPEED X DIA. of ALL DRIVERS. = SPEED X DIA. of ALL FOLLOWERS.

1st DRIVER. LAST FOLLOWER.



SPEED X NO. of TEETH = SPEED X NO. of TEETH.



SHEET METAL SEAMS OR JOINTS

Tin-plate is used mostly by the beginner in sheet metal-work. It consists of a sheet of mild steel which has been coated on both sides with tin to prevent it from rusting, and to make it suitable for household and other uses. The surfaces of the mild steel sheet are first chemically cleaned by immersing it in a bath of sulphuric acid. After this it is scoured with sand and then immersed in melted tallow, which acts as a flux. Then it is dipped in a bath of molten tin to coat it. After about five minutes in the tin the sheet is taken out and allowed to drain and cool. Then it is polished with bran; and before packing it is coated with a thin film of oil.

Finishing edges of sheet metal (see diagrams). *The Single Hem* provides a smooth edge for tin-plate and has a slight stiffening effect. Projects 1, 2 and 3 illustrate its application (page 107). The metal can be folded on a hatchet stake with a wooden mallet or by means of a bar folder.

The Double Hem has a greater stiffening effect than a single hem. It is made by folding the metal twice, so that both edges of the metal folded are smooth. This double hem is applied to the cookie cutter to give rigidity, and to the small cup to provide a seat for the bottom (page 107).

The Wired Edge, as shown in the accompanying diagram, makes a very smooth and strong edge. The simplest form of wired edge is the straight one shown, but other applications to circular projects are shown on page 107. Allowance for a wired edge for circular edges is usually $2\frac{1}{2}$ times the diameter of the wire used. For straight edges, such as the one shown, twice the diameter of the wire used is sufficient. Use a piece of tin-plate, $\frac{1}{4}$ " wide, and curl it around the wire to be quite sure that your allowance will apply correctly.

Lap Seam, or joint, is made by one plate overlapping the other and then soldering the joint. It is stronger than the "Butt joint", where there is no overlap. Both joints are quickly made, but they depend entirely for strength on the solder which holds the parts together.

Folded Seam: Two single hems are formed on opposite sides of the metal, as shown at (1). In circular work the metal is then bent around, presenting the hems as shown at (2), and hooked at (3) (thus called a "Folded Seam").

Grooved Seam: When the folded seam shown at (3) is locked by using a grooving tool, it becomes a "grooved seam", which makes a strong positive joint.

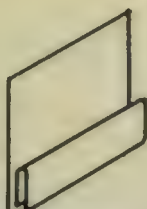
Allowance for Grooved Seam: Three times the width of the lock must be added to the pattern. This may be done by adding a single edge on one side of the pattern and a double edge on the other. If desirable, one-half the total allowance can be made on either side of the pattern.

Circular Lap Seam: This joint is used to fasten the bottoms on cylindrical objects. It depends on the solder to hold it.

SHEET METAL SEAMS OR JOINTS (*Continued*)



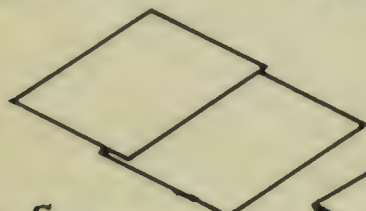
Single Hem.



Double Hem.



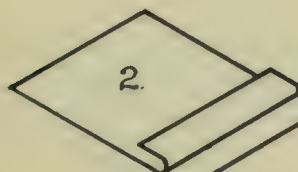
Wired edge.



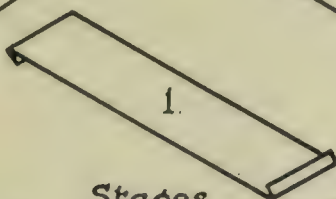
Lap Seam.



Butt Seam.

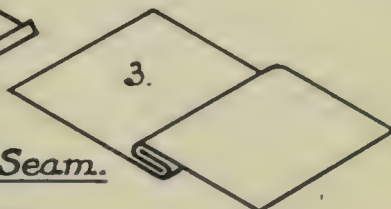


2.



1.

Stages
of
Grooved Seam.



3.

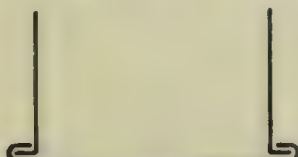


4.

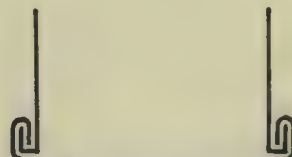
Grooved Seam.



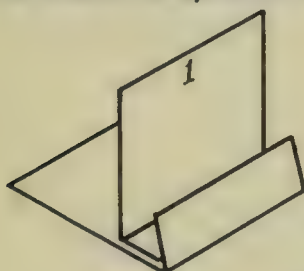
Circular Lap Seam.



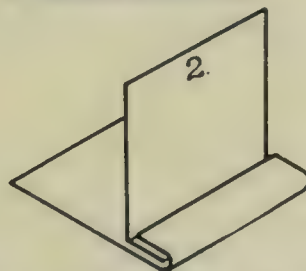
Folded Seam.



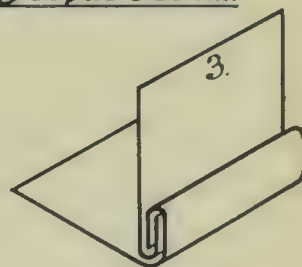
Double Seam.



1.



2.



3.

Stages of Double Seam.

The *Circular Folded Seam* is also used for fastening bottoms to cylindrical work. It provides a smooth, strong edge, which is closed down by a setting hammer.

Circular Double Seam: A very strong joint made by over-folding a circular folded seam, which makes the joint water tight.

Method of making a Double Seam: This is illustrated by diagrams (1, 2 and 3) at the bottom of the opposite page. This joint is used to fasten the bottom of tinware to the body.

SHEET METAL TEST

1. How is tin-plate made?
2. Sketch two methods of making the edge of a tin-plate project smooth and strong.
3. What is the name of the black scale on a soldering copper? What produces this scale?
4. How is the black scale removed from a soldering copper?
5. Why is the edge of sheet metal wired?
6. What is the allowance for a wired edge on tin-plate?
7. How is "killed spirits" made?
8. Name the fluxes used for soldering tin-plate, band iron, brass, copper.
9. What flux would you use for soldering two copper wires to be used to conduct electricity?
10. What kind of joint would you use for an article that was to be used in a household cooking oven?
11. Sketch the stages in making a grooved seam for a circular project.
12. Sketch three methods of fastening on bottoms to circular sheet metal projects.
13. Make a section of a sheet metal rivet joint.
14. Make a sectional sketch illustrating the two uses of a rivet set.
15. List the following soldered joints in the order of their strength: folded seam, butt joint, lap seam, grooved seam (place strongest first).
16. Why is copper used for a soldering bit?
17. Why is it not well to make a soldering iron red-hot?
18. What is a soldering paste made of?
19. What solders are used for hard soldering?
20. When is hard soldering used in preference to soft soldering?
21. Illustrate by sketches what you understand by "sweating" metals together.
22. What is the meaning of the word "flux"? Why is flux used in soldering?
23. What would be the length of a piece of tin-plate to make a circular project 6 inches in diameter with a $\frac{3}{16}$ inch grooved seam?
24. Can you boil water in a tin-plate article with soldered lap joints? Could you bake cakes in such a utensil?
25. What does soft solder usually consist of? What is its melting point?
26. How is tin-plate work polished?
27. What happens if tin-plate is heated to a red heat?
28. What is galvanized iron?
29. How can you soft-solder two pieces of metal together without the use of a soldering iron?
30. How would you clean a heated soldering iron that has already been tinned?

SHEET METAL PROJECTS



Baggage Label.



Match striker.

Card holder.



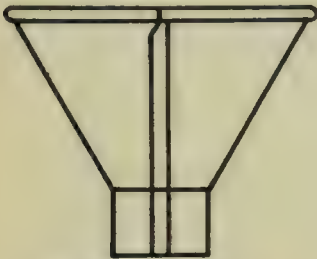
Square Cookie cutter.



Tray.



Cookie cutter.

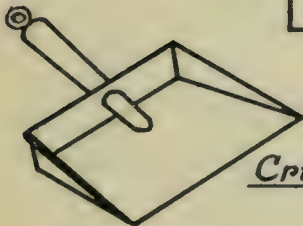


Jar funnel.

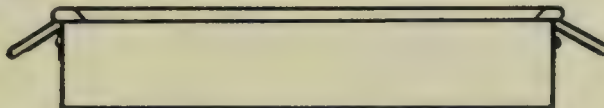


Small cup.

Scoop.

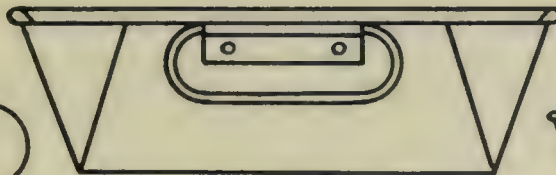


Crumb tray.



Bake tin (loose bottom)

Cup.



Bake tin.

Strainer.



TAP DRILL SIZES

TAP DRILL SIZES for 75% DEPTH THREAD.



U.S. STANDARD THREAD.			S.A.E. STANDARD THREAD.		
SIZE.	Number of Threads	Tap drill Size.	SIZE.	Number of Threads	Tap drill Size.
$\frac{1}{4}$ "	20	$\frac{13}{64}$ "	$\frac{1}{4}$ "	28	$\frac{7}{32}$ "
$\frac{5}{16}$ "	18	$\frac{1}{4}$ "	$\frac{5}{16}$ "	24	$\frac{9}{32}$ "
$\frac{3}{8}$ "	16	$\frac{5}{16}$ "	$\frac{3}{8}$ "	24	$\frac{21}{64}$ "
$\frac{7}{16}$ "	14	$\frac{3}{8}$ "	$\frac{7}{16}$ "	20	$\frac{25}{64}$ "
$\frac{1}{2}$ "	13	$\frac{27}{64}$ "	$\frac{1}{2}$ "	20	$\frac{29}{64}$ "
$\frac{9}{16}$ "	12	$\frac{31}{64}$ "	$\frac{9}{16}$ "	18	$\frac{33}{64}$ "
$\frac{5}{8}$ "	11	$\frac{35}{64}$ "	$\frac{5}{8}$ "	18	$\frac{37}{64}$ "
$\frac{11}{16}$ "	11	$\frac{39}{64}$ "	$\frac{11}{16}$ "	16	$\frac{5}{8}$ "
$\frac{3}{4}$ "	10	$\frac{21}{32}$ "	$\frac{3}{4}$ "	16	$\frac{11}{16}$ "
$\frac{7}{8}$ "	9	$\frac{49}{64}$ "	$\frac{7}{8}$ "	14	$\frac{13}{16}$ "
1"	8	$\frac{7}{8}$ "	$\frac{7}{8}$ "	18	$\frac{33}{64}$ "
$1\frac{1}{8}$ "	7	$\frac{63}{64}$ "	1"	14	$\frac{15}{16}$ "
$1\frac{1}{4}$ "	7	$1\frac{1}{64}$ "	$1\frac{1}{8}$ "	12	$1\frac{3}{64}$ "
$1\frac{3}{8}$ "	6	$1\frac{7}{32}$ "	$1\frac{1}{4}$ "	12	$1\frac{11}{64}$ "
$1\frac{1}{2}$ "	6	$1\frac{11}{32}$ "	$1\frac{3}{8}$ "	12	$1\frac{19}{64}$ "
$1\frac{5}{8}$ "	$5\frac{1}{2}$	$1\frac{29}{64}$ "	$1\frac{1}{2}$ "	12	$1\frac{27}{64}$ "

DRILLS for PIPE TAPS.

Size of Pipe.	Size of Drill.	Size of Pipe.	Size of Drill.
$\frac{1}{8}$ "	$\frac{21}{64}$ "	$\frac{3}{4}$ "	$\frac{15}{16}$ "
$\frac{1}{4}$ "	$\frac{29}{64}$ "	1"	$1\frac{3}{16}$ "
$\frac{3}{8}$ "	$\frac{19}{32}$ "	$1\frac{1}{4}$ "	$1\frac{15}{32}$ "
$\frac{1}{2}$ "	$\frac{23}{32}$ "	$1\frac{1}{2}$ "	$1\frac{23}{32}$ "

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